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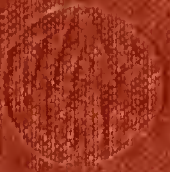

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BOOKS BY

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EXCEPTING TECHNICAL ILLUSTRATIONS OF PITTING AND RUSTING ALL PICTURES IN THIS BOOK ARE OF STRUCTURES PAINTED WITH PASTE RED-LEAD


U.S.S. NEVADA

RED-LEAD

AND

HOW TO USE IT IN PAINT

BY

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THIRD EDITION

REWRITTEN AND ENLARGED

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By A. H. Sabin

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PREFACE TO THE THIRD EDITION

In 1916 the writer prepared a little book telling the essential facts about red-lead paint; which, so far as he knows, was the first attempt to put them into connected and workable shape. This was published by the author, and privately circulated. It appeared to meet a public want; one well-known railway company ordered twenty copies; as many more were sent on request at various times to the Bureau of Standards; and on the day when these sentences are written a request was received from a State Highway Commission for several. A second edition, also privately published by the author, containing some corrections and with important additions, was made early in 1919; and as it is apparent that considerable advances in knowledge of the matters discussed have developed since it was first written, it seems proper and advisable to issue now, in the ordinary methods of the publishing business, what may properly enough be called a new edition, being written by the same author and including much of the original text, but rewritten and amplified to an extent so considerable as to make it almost a new book.

The truth is that the last few years have seen a great increase of interest in the subject; due, no doubt, to the rise in the cost of bridges and other metal structures, which makes their preservation more important; this incidentally leads to more discussion of it in the meetings of engineers; and partly to the comparatively recent introduction of red-lead in paste form, which, as is explained in the text, is made possible by improvements in the pigment, and increases its availability for more extensive use. The writer is willing to predict that the next step will be its sale as a liquid paint, ready for use; and that this will so much promote its use as a finishing coat and for general repainting, that the demand for it will be several times as much as now; perhaps will equal that for white-lead. Holding this belief, which is based on thirty years' experience and study of protective coatings, the writer has tried to give information as to the character of these liquid paints; for all paint must be reduced to this form before it can be applied.

In the text, the gallon is always the U. S. gallon of 231 cu. in., which is one-sixth less than the British imperial gallon (or the latter is one-fifth more than the U. S. gallon) ; but tables are appended for the use of those who use the British measures.

PREFACE TO THE FIRST EDITION

In a recent communication the engineer of the Illinois state highway commission described a bridge more than two hundred feet long over the Fox river at Ottawa, in which rust had formed between the web-plate of the rib carrying the sidewalk, and the flanges of the adjacent sections, developing enough expansive force to rupture the connecting rivets, which were of tough and ductile material; in one place there was ten feet with only one unbroken rivet, and in general only 10 per cent of the rivets connecting the upper and lower halves of the arch ribs were unbroken. The engineer says: "A circus outfit had been allowed to cross the bridge a short time before the examination was made. It was reported that the vibration was so great that oil lanterns hung from the overhead sway bracing swung up against the supports with sufficient violence to break the globes. It is also said that the leading elephant gingerly placed one foot on the bridge, then with a snort of disgust lumbered down stream a couple of blocks and swam across."

The writer knew of an attempt to lead an elephant across an old bridge over the Wisconsin river at

Portage, when the wise beast after entering the bridge backed out, went down the bank and swam across the deep and swift river, which was nearly seven hundred feet wide. It might be a good plan for every state to have an elephant for a bridge inspector.

Highway bridges are often like that; and while railway bridges are fairly well cared for, steel cars are not much better. The whole subject of painting structural metal, while not exactly neglected, seems to get more serious attention from the supply men than from the engineers, which is not as it should be. Engineering is not all a matter of ingenious design; that is a part of it, but a knowledge of materials is just as important and paint is just as much engineering material as steel or concrete, and is entitled to just as respectful consideration.

For thirty years the writer has been concerned with these problems; and for a long time has had unusual opportunities for knowing about lead pigments. Although these are everywhere recognized as important, it seems to him that red-lead is not known as well as it should be; and particularly that the great advances recently made in its production and character need to be made use of more generally; therefore, he has thought it proper to set forth in this public way his views and knowledge of the matter; and while he acknowledges his indebtedness to many others, and has tried to avoid giving opinions which are not shared by many who are competent to speak on the subject, no one else is responsible for what is set forth. Red-lead is not only an important but an interesting substance; its consumption for paint, in glass-making, storage-batteries, and many other things is increasing at an unprecedented rate, and any intelligent contribution to a knowledge of it ought to be worth reading.

A. H. SABIN.

RED-LEAD AND HOW TO USE IT IN PAINT

How Litharge Is Made

Lead has two principal oxides: litharge and red-lead. When lead is melted and exposed to the air it combines with oxygen from the air, the product being the protoxide, or litharge, the chemical expression for which is PbO, indicating that one atom of lead (plumbum) is united to one atom of oxygen. This is a yellow substance; if melted, as it sometimes is in process of making, it tends on cooling to crystallize in flakes, and is then called flake litharge; but if the temperature is skilfully regulated it may be in the condition of a powder. It is difficult to prevent melting in the hottest part of the furnace, hence litharge is generally uneven in fineness, having both fine and coarse particles; the latter may be powdered by passing the whole of the litharge through a suitable mill, if necessary.

How Red-Lead is Made

When this yellow litharge is again roasted, in contact with air, at a suitable temperature, it takes up a little more oxygen and turns red; it is then called red-lead, and its composition is expressed by the chemical formula Pb_3O_4. Although it contains only a third more oxygen than litharge, it is quite different from it; litharge is easily decomposed and enters into other chemical combinations, while red-lead is more stable; when exposed to the air litharge is acted on, but red-lead is quite permanent. Litharge is the form in which lead is commonly used when it is desired to make lead-containing compounds, while red-lead is used hardly ever in this way except in glass-making; at the intense heat of melted glass the red-lead enters into combination with it. This explains why it is so much better than litharge for an oil-paint pigment, and why the durability of red-lead is greater in proportion to its freedom from litharge.

When the litharge is put into the red-lead furnace the portion which is a fine dust is easily and completely oxidized; but the coarse particles become red on the outside while they contain unchanged litharge in the interior. Even prolonged roasting fails to change these further. This coarse red-lead, as a dry powder, probably does not reflect as much white light as that which is much finer; at any rate its color is a deeper and darker red, the very fine and highly oxidized sort being of an orange shade, whence it is sometimes called "orange mineral."

Orange Mineral

It is commonly thought that orange mineral is produced only by roasting dry powdered white-lead

Pennsylvania R. R. Bridge at Havre de Grace, Md.

PHILADELPHIA & READING R.R. CO.

(carbonate); being decomposed by heat, the carbonic acid is driven off, and the resulting litharge is roasted into a high-grade red-lead of an orange-red color; and, in fact, this is the common way of making it; but such a product is not distinguishable from any other red-lead of equal fineness and purity. The essential preliminary step is in some way to get the litharge into the condition of a uniformly very fine powder. This may be done by prolonged dry-grinding, as all manufacturers know; there is no secret about this, but it costs money to do it and requires a suitable plant. It can be shown, however, that the money is well spent, if a product of the best quality is desired.

Probably the largest use of red-lead is in making and maintaining storage batteries; and the makers of these have very different requirements from those for paint. They mix litharge with red-lead; and in fact they commonly prefer a red-lead only partly converted, containing about 70 per cent true red-lead or Pb_3O_4.

In the old-fashioned hand-operated furnaces it required great skill (as well as the best materials) to make the modern high grades, which are now made in mechanical furnaces, and operated by expert workmen; furnace samples are taken from every pan and chemically tested before the charge is finished, and in the best modern plants the operator can turn out anything the customer wants. Doubtless it will always be more expensive to make highly-oxidized red-lead, but as it is now done by machinery the additional cost is less than would naturally be supposed; and the high-grade product is better and more economical, as will be later explained, than the older sort; that is, for paint; not for battery oxide, or for glass-making, much being used for the latter industry; in fact, fine cut-glass tableware contains actual lead to the amount of from 30 to 50 per cent of its weight; the lead gives it brilliancy of luster, and good working quality in manufacture.

Objections to Red-Lead

But this does not make the best paint. While it is true that red-lead has for more than a hundred years been the standard paint for the protection of metal, and that a good deal of this was made of red-lead containing what would now be regarded as an excessive amount of litharge, it is also true that it was disliked by many, both painters and engineers. The most serious objections to it are two: litharge acts on oil at ordinary temperatures, the paint becoming viscid and ropy, and finally, if allowed to stand, making a hard, compact, heavy, cement-like solid; and second, such red-lead is coarse, and coarse particles in paint on vertical surfaces start "runs," the paint running down in drops and tear-like masses, leaving too little in their trail, and making unsightly lumps; also each of these coarse particles which remains in place extends through the entire thickness of the film from the underlying metal to the atmosphere, and forms a weak and defective spot in the film, as will be explained later.

A paint which is ropy does not brush out into a smooth, uniform film; its surface is composed of alternate furrows and ridges, due to the bristles of the brush sticking together in little bunches; at the bottoms of the furrows the paint may be too thin, and in the ridges the excess is waste, which might be economically applied to covering additional surface; moreover, a rough surface collects dirt, which may help to start corrosion, and it does not resist the abrasive action of the wind and dust as well as a smooth one. This fact is well known; it is recognized practise to leave varnish on exterior woodwork with its natural glazed surface, which will last longer than one which has been rubbed with pumice, as practised on interiors; also the extremely smooth surface of baked enamels, as on bicycle frames and the like, stands wear better because of its smoothness.

Let us bear in mind this fundamental fact, that fine (powdered) litharge makes fine red-lead, and such necessarily contains, other things being equal, more true red-lead (Pb_3O_4) than that which is coarser. In former times little attention was paid to its analytical composition; chemical analyses were rarely made, while now every batch is analyzed before it is drawn from the furnace; but the painter knew that he liked paint made with a fine pigment, and he chose fine (and therefore highly oxidized) red-lead if he could get it, and so the fine sorts came to be known as "painters' red-lead," and were saved for paint, while the coarser were sold for glass-making and the like. In this way painters' red-lead increased in true red-lead to 80 per cent, then 85 per cent, 90 per cent, and about 1909 the U. S. government engineers agreed to call for 94 per cent, allowing not more than 6 per cent residual litharge; this is their standard now. Such a product is finely powdered; in fact, to make it the litharge must be well ground before it is put in the red-lead furnace; and the large proportion of stable Pb_3O_4 greatly retards the action of the litharge on the oil, so that its brushing-out quality is good. Nevertheless, if allowed to stand in oil long it thickens and becomes viscous and finally hard; and the road to improvement obviously runs in the direction of making it finer in texture and consequently lower in litharge.

What High-grade Red-Lead Is

It has been found that certain chemical impurities in it prevent, or at least retard, this effect; but when sufficiently pure materials are used, and care is taken to prevent the introduction of impurities in manufacture, if the raw material is ground to an impalpable powder and the roasting is properly managed it is now possible to reduce the litharge to less than 2 per cent; and such a red-lead is so nearly inactive toward linseed oil that it may be safely ground in oil and put up, like white-lead, in

Boston & Maine R. R. Bridge, Mechanicsville, N. Y.

paste form, and it has for several years been on the market under the name of Dutch Boy red-lead-in-oil. It should be noted that the name Dutch Boy is a trade-mark; but that there is nothing patentable, indeed, nothing essentially new or unknown, about the manufacture of such a product; only proper machinery and additional care, skill, and labor.

It will be observed that this proprietary name appears in the tables appended to this book; while it is not intended anywhere to imply that this material is superior to any other paste red-lead of equal purity and composition, the fact that this is, in America at least, the oldest and best known make, and that it is composed of 100 pounds of red-lead to 7 pounds of oil, has caused the writer to use it as a standard; the tables are constructed for this mixture, and are not applicable to mixtures containing 8, 9 or 10 pounds of oil to 100 of the pigment, which have also been on the market. It was obviously necessary to choose some arbitrary standard, to prepare the tables.

Relation of Lead Pigments to Oil

All people who are experienced in the use of paint agree that if a paint is well applied, in a workmanlike manner, it will give better protection and last longer than if the coating is rough, imperfect and uneven. The study of paint films is not a simple matter, nor easy, but some fundamental truths are known. Oil paint consists essentially of two parts, the oil and the pigment. The pigment is supposed to be insoluble in the oil; but modern chemical investigations show that when a solid and a liquid are so intimately mixed, the solid almost always dissolves slightly in the liquid. Moreover, there is some sort of a surface attraction between them; the fact that a liquid may adhere with enormous strength to a solid is shown by the universal practise of lubricating machine bearings with oil; the shaft, which is itself heavy, is pulled with all the tension of a belt down on the bearing surface, and yet the surfaces are always separated by a film of oil which cannot be completely squeezed out even by the great pressure, which is applied along a very narrow strip of surface, as the shaft is always less in radius than the cylindrical bearing surface; this pressure may amount to thousands of pounds per square inch. Just how far from the surface this attraction extends is not known. We have all seen the experiments of putting the open end of a fine (capillary) glass tube into water, when the water rises in the tube, not from any chemical action, but because the glass attracts the water; and if a similar tube be put into the surface of mercury, the latter liquid will appear to be repelled, and will be depressed around the glass. It has long been known that wedges of dry wood put into holes in rocks may be made to absorb water so that they will swell and split the rock; this is due to surface attraction; so is the shortening of a rope when swelled transversely by wetting.

What is the cause of this and why some solids attract some liquids and not others is not known, but without doubt these phenomena are of importance in paints. For instance, if we wet red-lead or white-lead with water, and then stir into the wet mass some linseed oil, the oil will be attracted by the lead so much more than the water that the latter will be driven out, rise to the top and may be poured off, while the oil makes an intimate mixture with the pigment.

In the laboratory with which the writer is connected there is at the time of this writing a mixture of red-lead (98 per cent Pb_3O_4) with oil which was made from a water mixture in this way, which now, after standing a year, is a soft, uniform and complete red-lead-and-oil paste; and this method of preparing paste white-lead has been commercially practised for many years. Evidently these pigments have little or no attraction for water; and these combined qualities—little affinity for water and much for oil—must be of great value to an oil-paint pigment. No other pigments are known which show these qualities in so great a degree; other pigments, if wet with water, must be dried before they are mixed with oil. We may extract the oil, unchanged, from red-lead by washing it with ether, which attracts the oil more than the red-lead does; but there still remains a little oil, doubtless in intimate contact with the solid surface, which can only be removed by chloroform or benzol, which attract oil more strongly than ether; and chemical analysis indicates that a very little of the oil refuses to leave the lead even for these powerful solvents.

Difficulty in Removing Oil from Lead Pastes

The effect of the traces of residual oil on the subsequent analytical process is so pronounced that red-lead of 98 per cent Pb_3O_4 will, after extraction, appear to have only 97 per cent, the difference being probably due to the action of the minute amount of oil present on the chemical reagents used in the process. Action of this sort is due to surface attraction.

In writing a specification it is advisable to call for one or two per cent less "true red-lead" or Pb_3O_4 than is desired, because of the fact just mentioned. If the inspector were so situated that he could inspect the dry pigment before the oil is mixed with it, it would be practicable to call for the exact percentage desired, but this is seldom or never the case.

Fineness Is a Merit

The finer the pigment the more surface it affords, and the more strongly does it act on the oil, to bind the oil together and strengthen the film. In a pigment as fine as 98 per cent Pb_3O_4 the particles are so small that many of them, separated from each other by the oil, may overlay one another in the thickness of a paint film, and such a film will necessarily be better than one in which the particles are coarse, single ones reaching nearly or quite through the whole paint layer, and separated from each other by bodies of oil of appreciable magnitude.

Also, a paint like this will have a smooth surface, and be uniform in thickness, and such a paint will be so much better than one made from low-grade, coarse red-lead that it may plausibly be thought that its superiority is due to its fineness rather than to the comparative absence of litharge.

Makers of red-lead are generally able to supply the 94 per cent grade, and several companies furnish the higher quality. The 2 or 6 per cent not Pb_3O_4 is litharge (PbO), which is residual PbO, not yet converted into true red-lead; an excessive amount of litharge, say 10 to 15 per cent, makes the paint difficult to use, as it becomes ropy and thick, and if not used quickly combines with the oil, forming a hard mass in the container, of practically no use or value. These low-grade red-leads, rated as 85 to 90 per cent, make serviceable paints if mixed in the field and used quickly; but it is difficult to make a smooth and intimate mixture, and also requires more than common skill to brush it on properly; which explains the engineers' preference for the higher grade.

During the war the need for red-lead exceeded the supply. While a red-lead furnace will turn out a batch of 85 or 87 per cent in twelve hours, twice


LONG ISLAND R.R.CO.

this time, or more, is taken in making a batch of 94 per cent or over; and so the lower grade had to be accepted, being so much more rapidly made. But now the supply is adequate, and there is no reason why the former specifications may not be insisted on, greatly to the convenience and economy of the user.

It is unfortunately true that in some cases, during the war, a red-lead paint made with red-lead largely adulterated (to the extent of 50 per cent or more) with asbestine or silica, was permitted. These paints were supplied ground in oil, and it was represented that they were stable and permanent liquid paints; but at least one case is known where the buyer at this writing has on hand some ninety barrels of such paint which has become hard and solid, and is a total loss, though costing probably $150 or more per barrel. The loss of twelve to fifteen thousand dollars resulted from the purchasing agent listening to the persuasive words of the seller, who was after a profit of five or six thousand dollars; when he might have bought real red-lead for probably a quarter or a third more, and it would have been worth what it cost, always. And it would have been good paint.

The buyer should consider that he can get red-lead and linseed oil just as cheaply as anyone else, and there is no advantage in paying a high profit on an adulterated material.

Litharge in Red-Lead

In general, it may be said that in painters' red-lead litharge is objectionable. It is, however, maintained by some that the presence of 10 or 15 per cent of litharge is not harmful, and indeed is an advantage; but this is not supported by any arguments or essential facts; so far as the writer has observed, this is simply an assertion, unsupported or nearly so, which depends for its effect chiefly on vociferous reiteration. On the other hand, it is now well known that paint made from 85 per cent red-lead is quickly discolored when exposed to the weather; the litharge is converted, superficially, at least, into carbonate, sulphate or other compound, while a similar paint made with pigment of 98 per cent Pb_3O_4 retains its color for years, and is extensively used as a signal red, for which it is well fitted by its high luminosity. This can be accounted for only by considering the greater resistance to chemical change which red-lead always shows as compared with the lower oxide. Except for this permanence of color, the question is not one of much practical importance, for all admit the value of extreme fineness, and the desirability of having a paint which will not get ropy and show brush marks, and will not settle and separate quickly so that part is nearly all oil and another part nearly all pigment. These technical considerations would outweigh any minute theoretical advantage, if there were one, in a paint high in litharge; but in fact there is no advantage at all, except the slightly lower price per pound due to not pulverizing it sufficiently, and also a somewhat reduced price per gallon, due to its greater viscidity, which makes it possible to get brushing consistency with very little pigment. This latter fact is never put forward in its favor, because everyone knows that an abnormally low proportion of pigment is objectionable in every way; nevertheless, it probably has weight with some people whose own particular interests are favored thereby.

It seems to be only those who are opposed to pure red-lead paint of any sort who are doing this; and it may be that their object is to get all red-lead into disrepute, so as to promote the sale of something else. I know, of course, that there are a few old-timers, especially among the railway engineers, who have excellent master-painters, and well-trained and disciplined men, who will use 85 to 90 per cent red-lead, mix it in oil with much care, and then quickly apply it with skill, brushing it faithfully and laboriously; and all who know about painting know that such work is hard to beat, and is seldom equalled. But also it is seldom seen. What we are talking about, here, is what happens ordinarily. Some engineers would keep their bridges free from rust with whitewash; because they could keep continually at it. It does not matter much what such people use.

How to Use Litharge

Paint should be designed for the purpose for which it is to be used; and it would be foolish to assume that there can be no place where litharge may be a valuable ingredient in a paint; but that is no reason why painters' red-lead should not have as high a proportion of true red-lead as possible. If litharge is desirable, let it be added to the paint as such, and let it be as finely powdered as the red-lead itself; in this way the full value of all the ingredients may be secured.

To give an example: The engineers of the Metropolitan Board of Water and Sewers in Massachusetts apply to the interior of standpipes and conduits a paint made to contain 22.6 pounds red-lead of 98 per cent Pb_3O_4 in a gallon, the oil being a special boiled linseed oil; to this is added about 2.4 pounds powdered litharge, the purpose being to make a paint harder than pure red-lead because it is to be constantly under water, and water tends to soften any paint or varnish film. That is also the reason for using boiled oil. They get much better results from this than by using a red-lead containing the corresponding amount of litharge; partly because the paint has better working qualities, and also for some unexplained reason the litharge has a different and better effect when used in this way. Here is a rational and intelligent use of this material.

Lampblack in Red-Lead

In like manner lampblack may be judiciously added to red-lead. Formerly it was often added in large quantity to improve the working quality and prevent it from hardening; it is unnecessary to do that now with high-grade red-lead; even a little lampblack lessens considerably the adhesion of red-lead paint to iron or steel, and the first coat should always be pure red-lead; but it is an advantage to have a little in the next coat to facilitate inspection, and still more may be used in the finishing coat, if the color thus obtained is thought desirable. Lampblack should always be used in paste form, as dry lampblack is difficult to mix with oil; it has the highest oil-taking power of anything, lampblack paste containing oil 80 per cent and lampblack 20 per cent, by weight; at the other end of the scale is red-lead paste, containing 93.5 per cent of red-lead to 6.5 per cent of oil.

It is sometimes said that lampblack will not mix with red-lead; that it quickly comes to the top, and any painting done with such a mixture is streaky and uneven. This is so if dry lampblack is used; no amount of stirring will mix it properly, and it does come to the top. The reason is that it seems to stick together and the oil does not penetrate it, does not wet it as water wets salt, but acts as water does when dry flour is put in it; but if a little oil (comparatively) is put with the lampblack, and it is then ground through a mill, it is possible to make a paste of the oil and pigment, in which (as in flour paste) every particle is wet with the oil. If, now, the paste red-lead be mixed with a little more oil, say a quarter of its own volume, and some of the paste lampblack well worked into it, the mixture may be thinned with more oil with confidence that it will stay mixed. This is a general method, known to all good house-painters, for putting tinting-colors into paint, but it is especially true with lampblack, which will not not really mix at all if it is put in dry. Pigments differ as to the amount of oil they require to make pastes; at one end of the list is red-lead, 93½ pounds of which will mix with 6½ of oil, and at the other extreme is lampblack, two pounds of which requires no less than eight pounds of oil. In using the latter, remember it is only one-fifth pigment, the rest being oil.

Some Things Are Not Known

Why one pigment takes more oil than another is not known. It is sometimes said to be dependent on fineness, and in most cases it appears to be true that the same material takes more oil the finer it is, which is reasonable; but it does not hold as between different substances; thus, precipitated barium sulphate takes less oil than relatively coarse ground silica. Knowledge in this line depends on experimental data.

In general, the more oil we add to a pigment the thinner the paint; and as spirit of turpentine is a more mobile fluid than oil, we find, as we should expect, that it thins paint more than a like amount of oil; but I think no one would suspect, what is well known to all painters, that a given measure of it will thin a batch of paint as much as twice as much oil.

Turpentine

The real use of turpentine or other volatile thinner in paint for structural steel differs in some respects from its use in house-painting. In the first place, let it be said that the liquid called benzine twenty-five years ago has disappeared; it is too valuable in motor fuel to be used in paints. It evaporated rapidly, and paint or varnish made with it would suddenly stiffen as it went off, leaving brush-marks which with a slower-drying fluid like turpentine would have time to flow out and become smooth. The "mineral turpentine" thinners of today evaporate at least as slowly as turpentine, and when used purely as thinners are probably just as good. They are inferior to real turpentine in solvent action; and in priming coats on wood this is important, as the use of real turpentine in these enables the paint to penetrate the pitchy surface of the wood to some extent; but with steel there can be no penetration.

In some cases it is desirable to have a large proportion of pigment in the paint, and to secure good flowing quality it is expedient to use, first, the limited amount of oil which is desirable in the dried film, so that it will not be too soft, and then add enough "mineral turpentine" to make it fluid enough to brush easily. It is really used to increase the proportion of pigment, or, what is the same thing, to decrease the proportion of oil, in the ultimate dried film of paint. When used in this way turpentine is essentially a tool for the application of the paint. Thus, the Navy specification for 28 pounds of red-lead (pigment) to a gallon of vehicle is really equivalent to 32 pounds to a gallon of oil in the final film. Sometimes it is important to use turpentine in this way.

But in repainting it is often a good thing to use a little real turpentine, to soften the surface of the old paint, and make the new adhere better to it; and mineral turps does not do this, at least not so well. Mineral turpentine is one of the special distillates made in the modern practise of breaking up, by heat and chemical treatment, natural petroleum; it evaporates completely, not leaving any greasy residue as kerosene does, and has a nearly constant boiling point so that it all evaporates in a short time, say in an hour or so.

What Are Natural Paint Requirements?

What is a good specification for a structural paint? Many men have many opinions. In the first place, practically every master-painter will agree that different things may need to be painted differently. On the other hand, bookkeeping in a large corporation, such as a railroad, is made simpler by having as few formulas as possible; and a general superintendent will very likely say that more defects are due to using the wrong stuff in certain places than will result from a general-utility formula. Certainly red-lead lends itself better than any other pigment to such a formula, but let us consider the matter.

Elastic-Undercoat Cracks

In the first place, the more red-lead we have in a gallon the harder will be the paint. With most pigments more than a normal amount is likely to cause the paint to crack and peel; but white- and red-lead are not likely to do that because of the remarkable affinity already spoken of between the oil and the pigment, which latter is actually a source of strength to the film. But it is a good general rule that successive coats of paint should be, progressively, more elastic; the fundamental reason for which is that the sun and air harden the oil, and thus the outer layer gets harder than those beneath; and if the undercoat is soft and the outer one is hard, the latter, not having a sufficiently firm support, is liable to crack; "an elastic-undercoat crack," the painter names it. This is the most general cause of cracks in paint or varnish. Such a crack may not extend through to the foundation, but is objectionable in any case. For many places a series of paints, made on the following plan, would be satisfactory: priming coat, 33 pounds pigment (red-lead) to a gallon of oil; second coat, 30 pounds to a gallon of oil; third coat, 28 pounds to a gallon of oil. But it would be evident that for under-water work this reasoning will not hold; because exposure to water softens the surface, and it should be as hard as it may reasonably be; as has been said, this has been found to be like the priming coat just described, in some cases hardened still more with litharge. No additional coloring matter is used in successive coats in this case, since the prevailing opinion among hydraulic engineers seems to be that any such additions lessen the value of the coating. In a hot, moist climate similar reasoning holds, since excessive moisture in warm air prevents the surface from hardening to excess; mildew is sometimes found on paint which contains much oil in such regions.

Mildew, it may be remarked, is a fungous growth, spread by spores (which correspond to seeds of more highly developed plants) floating in the air; and the best preventive appears to be the use of paint containing a maximum amount of pigment and a minimum of oil, which becomes too hard and compact for the fungi to get a foothold.

How Much Pigment Is Needed

There must be some proportion of oil and pigment which gives most durability. If too much oil is


P.R.R. BRIDGE JOHNSTOWN PA.
MICHIGAN STREET VIADUCT BUFFALO
ELK ABBOTT STS VIADUCT BUFFALO

added, we finally get a film which is essentially an oil film, much less durable than a paint, and less impervious to air and moisture. If we add too much pigment we make a paste which, though fluid, is too viscid for a paint; still more pigment makes putty, which is not fluid at all, but a plastic solid; it has uses, but it is not paint. Many years ago engineering opinion seems to have settled on the proportion of 33 pounds of red-lead to a gallon of oil; such a paint contains 22.57 pounds of red-lead and 5.3 pounds oil in a gallon. This proportion is still justly regarded as excellent where extreme durability is required, and is used by several important railroads; and the United States Navy formula, though apparently on the basis of 20 pounds of red-lead in a gallon, is really nearly the same, because in the vehicle there is some turpentine and some turpentine drier, which are volatile and raise the proportion of red-lead considerably.

The Navy specifications must not be confused with those of the Shipping Board, which were more loosely drawn and more laxly enforced. Contractors to the latter sometimes reported that they could not get red-lead; which I believe was never true; on this ground they were permitted to use other paints; and sometimes extreme haste to finish a ship caused the use of a red-lead paint made so that it would dry hard throughout overnight.

The New York Central Railroad calls for the proportion of 25 pounds red-lead to a gallon of oil for shop coat (which is also the Canadian Pacific practise, though the latter is said to be 30 pounds to an imperial gallon, which comes to the same thing); but for maintenance some of their engineers use mixtures as high as 23 pounds in a gallon including drier, which is more than the old 33 pound formula. On the great Hell Gate steel-arch bridge, that distinguished engineer, Mr. Lindenthal, used red-lead on surfaces to be bolted or field-riveted in the proportion of 24¾ pounds of red-lead in a gallon of paint, or 37½ pounds to a gallon of oil. This is practicable only by using red-lead containing 98 per cent Pb_3O_4, which is both finer and more fluid than the lower grades. This was pronounced a satisfactory working paint by the painters; and the writer has had a similar mixture used by several painters, at different times, on metal gutters and valleys in roofs, with excellent results and the approbation of the workmen.

Twenty-five pounds of red-lead to a gallon of oil, or about 18½ pounds in a gallon of paint, is probably the most common railroad specification; since it is unusual for specifications to be lower than this, it is doubtless below the average of specifications; on the other hand, shop practise is to use much less in cases where the specification calls only for a coat of pure red-lead paint without naming the proportion; 20 and even 18 pounds to a gallon of oil is common, and the writer has known of as little as six pounds of red-lead in a gallon of paint; which should be a warning to specification-writers to fix the quantity of pigment they desire used. Also, the writer has known of a red-lead paint containing about 14 pounds of red-lead and weighing altogether 20 pounds per gallon which was used to fill a specification calling for red-lead paint containing 20 pounds of red-lead in a gallon of paint; and this should be a warning to inspectors to see that the specification-writer's intentions are carried out.

How Many Coats?

For more than a hundred years red-lead has been used as a paint for iron, and it has been known that however hard it may become with age it is never brittle, and never scales off if it was originally applied to the metal, not to rust or loose scale; and that it excels most coatings in adhesiveness. But, as has been said, much of that formerly made did not brush out smoothly; and a rough surface does not wear well; the grooves and ridges hold dust and mud, and the prominences wear off by the abrasive action of the weather; it does not look well even when new, and worse when old; the litharge content is acted on by the carbonic acid in the air, which converts it, superficially, into white-lead, making the red color fade out, and giving the impression (which is not correct) that the paint is breaking up throughout. So the practise arose of applying it as a first coat only, and covering it with a couple of coats of some finely-ground, easily-brushing paint which levels the surface, making it smooth and, perhaps, glossy. This was based on knowledge of the art and good sense. But this gave rise, not unnaturally, to the erroneous belief that red-lead had some inherent weakness which unfitted it for direct exposure. As a matter of fact, red-lead is not less durable, as a finishing-coat, than white-lead, and probably more so; paint made from paste red-lead is as finely-ground as white-lead, and dries with a smooth, glossy surface; it has frequently been said that it looks, when new, as though varnished; of course, in a year or so the oil surface becomes dull. Being almost free from litharge the color is tolerably permanent, enough so that it is largely used as a signal red; but as a finishing coat most people prefer it tinted to a brown or chocolate color, which may be done with a little lampblack. There is really no reason why it should not be used for all three coats; true economy is secured only by having the whole of the film of the most durable material; no one would think of painting a house with one or two coats of white-lead and finishing with some inferior paint; bridges have far less surface than houses of equal cost, and are less durable; they justify at least as much care.

Lead is naturally an inert metal; it never rusts, as iron or zinc do; it makes the most permanent roofing known; to oxidize it we have to melt it and agitate it for a long time in the presence of hot air in a furnace; roasting for two days and nights is often practised to make red-lead. In this state it is extremely stable to atmospheric action; it is not an electrolyte, and does not conduct electricity; a dry film of red-lead paint is said by a high authority to equal in this respect a film of the best rubber of equal thickness. In so far as insulation checks local chemical action, this is a good quality in a paint for metals.

The Finishing-Coat

The question of a finishing-coat for metal structures is one of considerable interest. There is no good sense in making it of readily perishable material. In finishing a fine carriage it has for a hundred years been the accepted practise to have the last coat of varnish the most durable possible, made of the best materials, and costing the most money; it takes the wear; it is called in the trade, and on the label, Wearing Body Varnish; and if it is right, it is the crowning triumph of the varnish-maker's art. The last coat for house-painting is in like manner made with ultimate care, at once heavy, elastic and glossy; the new apprentice is not allowed to put that on. But, for reasons already told, these principles have often been forgotten by the engineer, who in this matter has not the constant bread-and-butter-earning practise of the master-painter to stimulate his critical observation and study of the problem.

It is time to review this matter. Structures cost more than they formerly did; paint is but a minute part of the cost; longer life and safer condition justify more care and expense. In former times labor cost, in favorable conditions, at least as much as the best paint; often twice as much; I have seen a detailed expense sheet kept by a city bridge engineer of long experience which showed the cost of the paint to be only one-sixth of the total cost of thorough cleaning and repainting. Now, with enormously greater labor cost, and the paint cost in less proportion to that of the structure, a different and wiser practise is required.

Highway bridges frequently and railroad bridges less often (but actually in large numbers) have been finished in light color. The fundamental principles of light colored paints are well known. In the first place, they are modifications of white paint; a light colored one cannot be made from a dark base. There are only two or three available white pigments. White is without any dominant color; and any white substance, such as powdered gypsum, or chalk, if it can be obtained in large crystals, is seen to be transparent. In powder they reflect the light from their numerous irregular minute surfaces, and thus appear white, as snow is white although ice is clear. If we put snow in water it loses its whiteness, and if we put a white pigment into an oil or other liquid with which it has similar relations to light it is seen to be transparent; but if it refracts light more strongly than the oil does it remains white and opaque. The principal white pigments are white-lead, basic lead sulphate (also known under a proprietary name as sublimed white-lead), zinc oxide or white zinc, and zinc sulphide, which is the white part of lithopone.


RED RIVER BRIDGE V.S.&P.RY.
SHREVEPORT LA.
C.C.C.&ST.L.R.R. BRIDGE
DAYTON, O.
C.C.C.& ST.L. R.R. BRIDGE DAYTON, O.
C.C.C.& ST.L. R.R. BRIDGE MIDDLETOWN O.

Another white substance, titanium oxide, is apparently coming into use, but is as yet too costly to be used pure. Zinc sulphide is not permanent, at least for weather exposures, and may therefore be left out of account. Basic lead sulphate has never been used alone; it is a substitute for white-lead in the so-called "ready-mixed" house paints, and seems to be well liked by the manufacturers of these; but for a finishing coat over a dark under-coat it is not practicable to use any pigmentary mixture which contains a transparent substance like silica, silicates, or barytes, because they reduce the opacity of the film. Now, even the most opaque white, which is white-lead, will not conceal the under-coat completely if only one coat is applied; red-lead, for instance, will impart a reddish or pink color to it; and any more transparent paint will be noticeably worse; as a general rule it will be found desirable to depend on one coat of the light or finishing paint, to save expense.

Pure white, however, is not often desired; and the addition of a very small amount of colored pigment, just enough to make a light grey, or what is called a light stone-color, such as may be seen in the sheet of color samples in the back of this book, will so increase the opacity of white-lead that one coat of it may be depended on to completely hide a paint so brilliant as even pure red-lead. And the addition of this small amount of color increases its durability; because all pure white paints are somewhat translucent, and if the chemical rays of the sunlight enter them the chemical action thus set up tends to destroy the oil, and then the paint wears off. This is why the best white paint is less durable than the best colored paint. This is a good reason for using, for this purpose, a pure white-lead paint, tinted as little as will produce the needful opacity. Naturally, the more transparent the basic white paint is the more coloring matter it will require; which brings another thing into consideration; one of the objects desired is that the paint shall reflect the sunlight and with it the heat; these are absorbed by dark paints, and things having a dark color become hotter in the hot sunshine than light ones. It is well known, for example, that tanks for volatile oils, such as gasoline or motor spirit, are painted white for this purpose; and some engineers consider that a bridge which is dark in color will become hotter and be subjected to more strain from this cause than those which are light colored. If this is a matter of painting, pure white-lead is indicated; for while white zinc is in itself highly opaque, it is well known that it requires so much more oil that it makes a more translucent film.

Salesmen sometimes say that lead paints should not be used around oil refineries because the crude oil contains sulphur which will permeate the atmosphere and attack the lead; but if there is sulphur in the oil it is in chemical combination, and can be separated from it only by chemical treatment; it does not get into the air at all. I have often seen in such places tanks which had been so long painted with red-lead that the linseed oil of the paint had weathered off from the surface of the film, and the litharge component of the red-lead had been converted into white-lead by the carbonic acid which is in the air, and some of this dry, powdery white-lead could be rubbed off by the hand; but it remained white, there being no sulphur to attack it. For all practical purposes the action of sulphur on paints may be left out of account, except in such extreme cases as railway round-houses and enclosed train-sheds.

Mixed Pigments

The doctrine that mixtures of pigments are better than single ones is sedulously put forth by some makers of mixed paints and the experts, or perhaps pretended experts, employed by them; but, while it is undoubtedly true that for certain purposes mixtures of pigments are necessary, there should always be a perfectly definite reason for the introduction of each ingredient in every separate instance, quite aside from the profit it affords to the manufacturers. Many of these fully indorse this statement, and give no support to the loose talk indulged in by others; they know by experience as well as common sense that any who make paint on that plan, and give the customer the best product their skill can devise, build up a business on a sound basis, which in the end will prove better than one depending on alluring advertisements.

Good + Worse Is Not Better

While no one should pretend that the particular pigment he fancies is the only one which has any merit, it is not likely that for durability, or the protection of metal from corrosion, a mixture of pigments is ever better than a single one, except in cases where an inferior paint is improved by the addition of a better one; that is, a good paint is not made better by being mixed with a worse. And yet there are people who admit that silica, for example, made by itself with oil into a paint, is worthless, either as to durability or anything else, but who maintain that 30 or 40 per cent of such paint may profitably be added to a red-lead paint. They do not say it in exactly that form: they say the paint may contain in its pigment part 10 per cent of silica. But the volume of a pound of silica is more than three times that of a pound of red-lead, and its oil-taking power is higher, and to make a paint containing 9 pounds of dry red-lead to 1 pound of silica it is necessary to add to 2 gallons of red-lead paint more than a gallon of a silica paint of like consistency. There is no doubt in the mind of the writer that such a paint is much inferior to one of pure red-lead; also that no pigment which has ordinarily been used in paints for steel protection will improve red-lead for that purpose. Other things may be put in for special purposes, as lampblack to color it, but not to make it more durable or better.

Volume Proportions

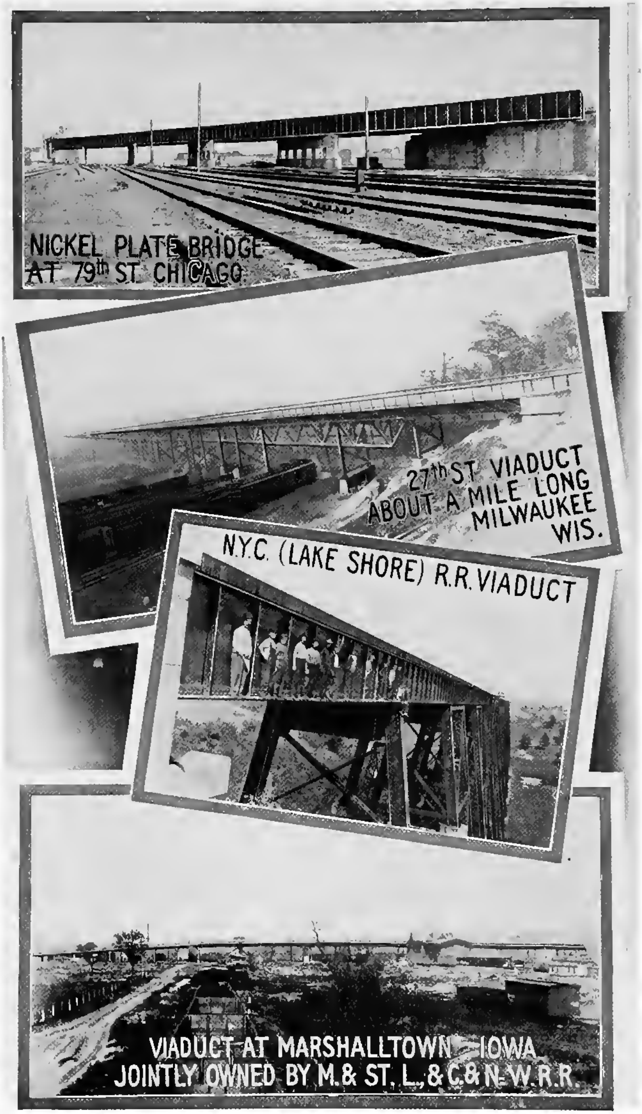
Probably it will not be disputed that the general opinion as to the composition of red-lead paint among engineers is that 33 to 25 pounds of this pigment should be used to a gallon of oil; which is equivalent to saying that in a film of such paint one-third to one-fourth of the volume of the film should be red-lead, according to the uses to which it is put. The effect of using a mixed pigment of nine-tenths red-lead and one-tenth silica is to reduce the red-lead so that instead of a minimum proportion of one-fourth it constitutes but one-sixth of the volume of the film; which, corresponding to 15 pounds to a gallon of oil, no one would admit to be enough; moreover, the coarse particles of the silica, extending clear through the film, make weak places and danger spots. Such a paint will be offered at not less than nine-tenths the price of straight red-lead paint, although it costs a quarter less to make; there lies the profit, and the reason for recommending it.

These same people who are insistent on adulterating red-lead are equally ready with experimental proof, of their own making, that graphite or lamp-black are not only worthless, but actually induce corrosion; but they also say that if these harmful things are mixed with red-lead and small amounts of two or three other things, according to methods best known to themselves, the bad qualities of one are counterbalanced by those of another, and thus their virtues are allowed to come out and excellent results may be expected. The truth of it is that no single-pigment paint meets their approval; only such complex mixtures as can be compounded in a paint factory and sold at a profit, which increases with the difficulty of understanding the explanations.

The fact is that loading a carbon paint with barytes or silica is spoiling good material; some of these pure carbon paints are of unsurpassed durability on wood, and, while they do not answer nearly as well on metal, that is far from saying they have no merits for that purpose. The trouble seems to be that they take too much oil, and are thin and often do not adhere well; but if they are to be bodied by additions, let something be used which has merit in itself, even if it does add to the cost. It is not well to be at the mercy of somebody else's purchasing agent, who may know the price of everything and the value of nothing; there are such.

Simplicity and Complexity

Simplicity in materials is not always possible, but it is a great advantage, and in using red-lead the best results are to be had by the least complex means. Calculations which involve only one or two pigments, oil, drier, and occasionally turpentine, often seem sufficiently intricate; but by learning a few essential facts and giving a little purely mathematical consideration to the operations, they may be


NICKEL PLATE BRIDGE
AT 79th ST. CHICAGO
27th ST. VIADUCT
ABOUT A MILE LONG
MILWAUKEE
WIS.
N.Y.C. (LAKE SHORE) R.R. VIADUCT
VIADUCT AT MARSHALLTOWN — IOWA
JOINTLY OWNED BY M.& ST. L., & C.& N-W.R.R.

mastered by anyone who cares to take the trouble. Indeed, all engineering is composed of mathematics and materials; but the ordinary structural engineer is not supposed to concern himself with what goes on in a general paint factory, nor is it needful that he should. The necessary data will be given in another place, all together.

Complexity in paints makes it impossible for the average consumer to understand their composition. A paint analysis always should give, first of all, the weight per gallon; it never does. To compute this from the analytical results is not absolutely impossible, but it is so to most people. For example: there is a well-advertised and widely sold red-lead-and-graphite paint, half the pigment being represented to be red-lead. Analyses by disinterested and capable chemists, running over a period of 16 years, show a sufficiently constant composition; pure linseed oil, with pigment half red-lead, as advertised. What does the buyer think? He thinks that he gets a paint halfway between a pure red-lead and a pure graphite paint. If he is more than commonly well-informed he knows that graphite paints always contain some of the natural rock in which the graphite is found; the graphite paint men all agree that a little of this, being well ground up, improves it by giving it the necessary grit which the pure graphite lacks. Maybe it does; I don't know. But I have my doubts. That is about all the information the buyer is likely to get. If he knew the weight per gallon, he could multiply it by the percentages the analysis shows, and he would then learn that it contains about 5 pounds of red-lead, 1½ pounds of graphite and 3½ pounds of "gangue," nearly all silica, and that it could be matched by mixing a quart of red-lead paint, a quart of graphite paint, and two quarts of silica paint. That is considerably different from being half-way between a pure red-lead and a pure graphite paint. And this is not a mail-order proposition, nor made by a fly-by-night concern, but is from a highly reputable and old-established company; and it really is a pretty good paint. The reason why it is so much better than would be expected is that it is of heavy body; I myself saw more than 50 barrels of it put on smooth, new steel plate at a spreading rate of 325 square feet per gallon, in hot weather; taking about 2¼ times as many gallons as would be required of a good red-lead paint, and probably at least 3 times as much labor. It ought to be good.

An inferior paint spreads over less surface because it is made of greater viscosity, since it is necessary to have a thicker film to get the required freedom from porosity and have fair wearing quality. With a free working paint of high durability the painter can rub it out easily with the brush, getting better results with much economy of time, which, with a high rate of wages, reduces the cost of the job. Extra repaintings are a squandering of money—not simply for the paint, but still more for the labor, which is the principal item.

Theory of Inhibition

A few years ago there was a great outcry about the value of "inhibitive" pigments. The theory involved the assumption that all paint coatings are porous to water, that the water in contact with the iron is "ionized," and that this causes corrosion; further, that certain substances, notably salts of chromic acid, used as pigments, although ground in oil and the oil dried into a solid film, are still accessible to water, and although insoluble in water, as the term is generally used, are yet slightly dissolved, and in some way free to wander about the inner surface of the solid and strongly adherent film, and attack these ions of the water and put a stop to the corrosion. When we consider the number of ingredients of the paint; that the dried oil is still a reducing agent; that it always contains not merely an appreciable amount of catalyzers (driers), but enough to make it dry five or ten times as quickly as pure oil; that there is good reason to disbelieve that a good paint film is practically permeable to water; and that all this pigment material is locked up in an insoluble cement of linoxyn or "oil-rubber," it is certainly mysterious how the chromic acid gets free and acts at just the right time. It is no doubt true that, as Hamlet said,

"Imperious Cæsar, dead and turned to clay,
Might stop a hole to keep the wind away,"

yet, as the conservative Horatio suggests, " 'Twere to consider too curiously to consider so." There are too many improbable things about this inhibition process. According to its advocates, red-lead is a material of no special merit, but the Pennsylvania R. R. Co. used it on an Ohio river bridge at Louisville, where three coats when the bridge was new and enough to make three more applied later kept it from any sign of corrosion for 46 years, from 1870 to 1916; and the writer knows of a large bridge on which the paint, not containing any "inhibitive," but on the contrary rich in "accelerator," which was put on when the bridge was built, has protected it more than twenty years. "Inhibition," however, is a sonorous advertising term, and, like all cure-alls, is attractive to many. The fact remains, that so far as our experience goes, a bridge cannot be kept from rusting unless we keep the air and water away from the metal, and it will not rust if we do. That is what paint is for; a good paint does it, and, on the average, a good red-lead paint does it longer than anything else.

About the only chemical activity we are entitled to look for in a paint film, after the oil has dried, is that which may lead to its destruction. The enthusiastic seller of paint sometimes goes so far as to tell that it will deoxidize rust; also they talk about the pigment being chemically basic, to neutralize the acid which would cause corrosion. No doubt some pigments are so; white zinc is, and white-lead, and carbonate of lime, whether in the form of whiting or of marble dust, and so is red-lead, and carbonate of barium which sometimes takes the place of barytes—the substitute for a substitute,—but if they were chemically active, and the acid could get into the film, how long would they last? The supply of acid, if enough to eat up the iron, is practically unlimited. That is not what a pigment is for; we are, indeed, entitled to expect it to be reasonably permanent in itself; but what we are really after is an impervious film, the ingredients of which agree among themselves, so as to hold each other together, and be non-porous and durable. Some one told the late L. L. Buck that his paint would penetrate a sixteenth of an inch into iron.

"Young man," said that old wise man, "I wouldn't tell that if I were you."

Probably not; "but," said Mr. Buck to me, "I shouldn't wonder if some engineers believed that." Fifteen years ago a really capable manufacturer tried to make a Portland cement paint; it is easy enough after the event to tell why it did not work; but to this day we hear, now and then, talk of putting Portland cement in. That isn't selling paint; that's selling psychology. Do not be flattered into believing that fourteen weeks in chemistry fourteen years ago makes a man an expert. Go and see a chemist.

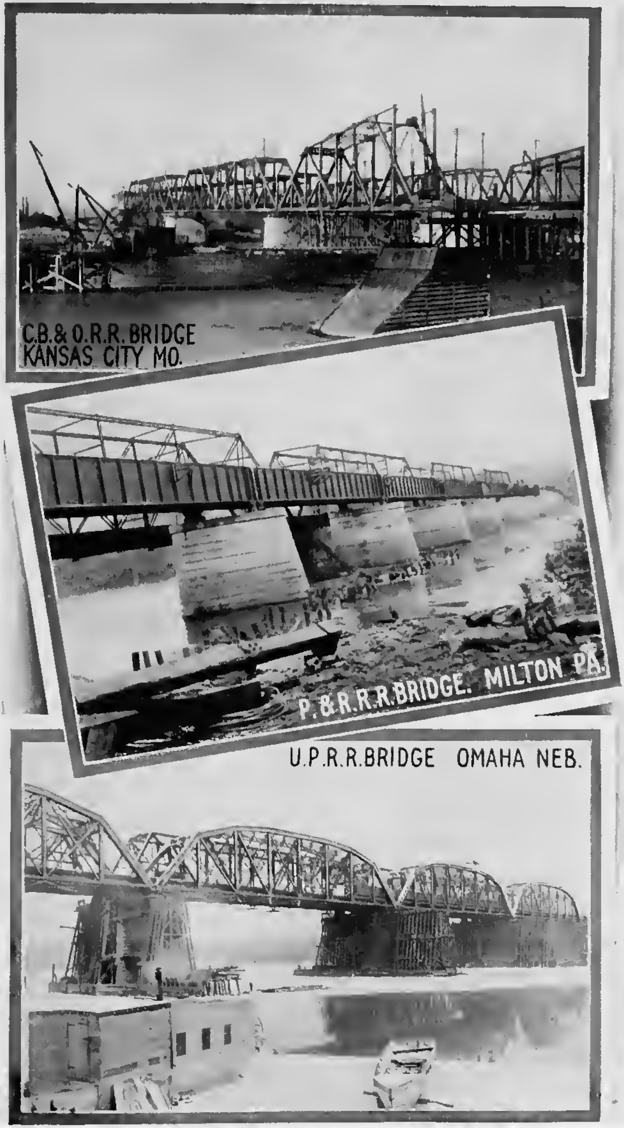
The Havre de Grace Bridge

In this connection it is worthy of notice that in the Havre de Grace bridge paint test, the only test of paints for metal designed and conducted by the Society for Testing Materials, none of the paints contained what the inhibition theorists regard as inhibitory pigments, and several were of the type supposed to be most accelerative of corrosion, yet nearly all protected the iron, except from mechanical injury, perfectly for five years, which absolutely could not have been so if that theory is of practical application; and at the end of the test after seven or eight years, the best paints were unmixed red-lead, and the best of all was highest in Pb_3O_4 and nearly free of PbO; and next to straight red-lead paints were those containing red-lead. After the test was completed this bridge was repainted throughout with paint made from paste red-lead of high-grade, 98 per cent Pb_3O_4, twelve years after its construction.

It is also worth noting that, in the Transactions of the American Society of Civil Engineers, Vol. LXXVII, p. 963, an eminent bridge engineer (now chief engineer of an important railroad) gives his experience with red-lead containing over 98 per cent Pb_3O_4 since 1898, showing that it is much better in all respects than red-lead of lower grade; and the same engineer is at the time of this writing using only this grade of red-lead.

High-Grade Red-Lead Has Been Long Known

In various books and journals of chemistry are records of analyses showing that for many years occasional lots of this high-grade red-lead were


C.B.& Q.R.R. BRIDGE
KANSAS CITY MO.
P. & R.R.R.BRIDGE. MILTON PA.
U.P.R.R.BRIDGE OMAHA NEB.

found in commercial use; but the analysts and the users are long since dead, and no record remains as to what the material was used for, or with what results. But in the case of the Louisville bridge already referred to, the records show that as long ago as 1870 it was painted with forty pounds of red-lead to a gallon of oil; now, if this had been the low-grade red-lead common at that time, such a mixture would not have been a workable paint, but more like a paste or putty, owing to the quick action of the litharge on the oil; so it is practically certain that it was high in true red-lead; such material was made and only such material could have been used; therefore, we may say, it was used. Mr. Cox, superintendent of this bridge, is authority for saying that the new bridge, which, for increased weight of traffic, is to replace the old bridge, is painted with a mixture of 67 pounds of Dutch Boy red-lead paste to one gallon of linseed oil.

Heavy Paint

This paste contains 6.54 per cent of oil, hence 67 pounds contain 4.38 pounds oil and 62.62 pounds red-lead; add 1 gallon=7.75 pounds oil, makes 12.13 oil; and this is very close to 40 pounds dry pigment to one gallon of oil. This paint had excellent working quality and the appearance of the painted structure is extremely good. About a hundred thousand pounds of the paste has been used on this bridge, or about fifty barrels of paint.

Water Tanks and Pipes

It has been said that red-lead paint is used on interiors of water tanks, standpipes and conduits. Twenty or thirty years ago it was thought that this might contaminate the water with lead salts, which would occasion lead-poisoning; but consideration of the fact that red-lead paint is almost universally used on the outside of ships suggested the conclusion that as the paint does not decompose, but remains to give good service for years, it must be that the lead does not go into solution, and therefore is perfectly safe. At first attempts were made to evade the question; to get the good qualities the paint was made half red-lead and half some other material, as graphite, and the red-lead was reduced still more in the finishing coat. Probably this was also done to avoid prejudice, for there was much loose talk about lead-poisoning from lead water-pipes; but in later years this has been so completely disproved that the cities of New York and Boston and many more will not allow any but lead pipes to be laid between the street mains and the houses; and now the most eminent sanitary engineers, such as those of the Massachusetts state organization referred to, are using pure red-lead for all three coats on such work. No lead is found in the water, and the paint is quite satisfactory.

It is probable that in the future this well-known and standard material will be more generally used for such purposes, rather than complex bituminous mixtures of unknown composition, which cannot be

Penstocks—City of Los Angeles

defined in a specification nor analyzed for a control. Certainly no paint mixtures of known composition can compare favorably with it.

It has long been believed by observant workmen that paint and varnish shrink as they become dry. More than twenty-five years ago the writer noticed that dried raw oil was heavier than water, having increased in specific gravity more than could be accounted for by its increase in weight by oxidation, which really is very little at the end of a year; and recently Mr. G. W. Thompson, in a carefully designed series of tests, has shown with more exactness the amount of this shrinkage. The practical application of this is that it probably explains the well-known and undoubted tendency to the appearance of rust on rivet-heads and angles; the oil first forms a skin, and as this shrinks it squeezes the more jelly-like, unhardened oil away from these prominences. To allow for this, in a book published in 1898, I advised that after the first coat had been put on and had dried, all rivet- and bolt-heads and angles should be specially painted, with a spotting or striping coat; after this the next full coat should be applied. This has been done, not generally, but at least quite extensively; and in the case of structures like water-mains and pipe-lines, which from their location are impossible, or nearly so, to repaint, this precaution is particularly recommended.

The practise of the hydraulic engineers for the State of Massachusetts has been briefly described; it is followed by many others; recently, in the case of some large water mains, by the engineers of Minneapolis and of Los Angeles, who used three coats of pure red-lead. When the paint is to be exposed to water it is not desirable (as it is on bridges) to have succeeding coats more elastic, because the action of the water tends to soften any paint, and the surface should be hard. Boiled linseed oil is advised as the vehicle in such cases, because it makes a more varnish-like film, and does not hydrolize (soften by the chemical influence of water) as much as raw linseed oil sometimes does.

This reasoning also applies to painting the outside of pipes which are buried in the earth, and thus are removed from the action of sunlight; but unless these are in wet earth they do not require boiled oil. In general, raw oil, with a little drier if necessary, is somewhat more durable than boiled oil; a mixture of equal parts of raw and boiled is much used in all kinds of paints where more than usual hardness is wanted.

The writer recently discussed the use of free litharge with the principal authority of the Massachusetts board; and it appears that after many years' experience they are strongly in favor of using red-lead containing as little litharge as possible, and adding fine powdered litharge to it where it is to be specially resistant to water. They are confirmed in their original opinion that such a paint has excellent working (brushing) qualities, and is more satisfactory. This seems to me to be essentially of the nature of a discovery.

Boiled Oil

The reason for using boiled oil is that such oil partakes of the nature of a varnish, and does not hydrolyze so readily or so much as raw oil; also the presence of a large proportion of red-lead tends to prevent that action. Originally, boiled oil was made by putting raw linseed oil into an open kettle with a proper proportion of driers and heating it, with continual stirring, for several hours at about 500° Fahrenheit. Long continued heating at a high temperature causes oil to dry with a gloss, like varnish; such oil tends to "skin over" and not dry thoroughly to the bottom, but this is remedied to some extent by admixture with a large proportion of pigment, especially lead pigments, which have a strong affinity for oil; and in any case the long time allowed for drying, as has been advised, secures complete hardening of the film. Boiled oil is commonly made in these days by cooking the oil and drier in a tank heated by steam pipes; part of it, usually 20 or 25 per cent, is first heated with all the drier at a rather high heat until the drier is dissolved, then the rest of the oil is added and the whole heated at a somewhat lower temperature; this gives an oil of pale color, and generally satisfactory; but for very exacting requirements the differences in boiled oils are considerable. There are as yet no recognized and sufficient specifications for boiled oil, and a man must be an expert to judge between them; judging is based on concurrent and parallel tests.

Elevated Water Tanks

The chief engineer of one of the largest companies which build factory water tanks erected on tall steel frameworks calls attention to the fact that these present an unusual problem in painting. This is necessarily left until the construction is complete; then the working force goes elsewhere, and one or two painters are left (generally one) to climb about the thing and paint it as best they can. It has got to be painted; the contract calls for it; and it is impracticable to keep a dozen high-priced iron-workers on the job to occasionally set a scaffold, and the rest of the time uphold the scenery. There is the painter, perhaps a hundred feet above the ground, in an uncomfortable and sometimes dangerous-looking place; generally the wind blows up there and sometimes it is too cold for comfort; and he has no help or sympathy from anybody. The paint, put on a cold surface in the wind, chills and is stiff; how can he brush it out to the ideal surface the owner expects? What I say is, make the paint rather thin with oil, say the equivalent of 22 to 25 pounds of dry red-lead to the gallon of oil; and then thin it a little with mineral turpentine, so it will flow easily, more fluid than you would use in ordinary bridge work, and this thinning has got to be left to the judgment of somebody, either the painter or the inspector, if there is an inspector, for it will vary from day to day according to the weather. And it is useless to expect the painter to use a very stiff brush, or to brush it very much; fortunately it is new metal and clean. To make up for these conditions, let the specifications always call for at least three coats of pure red-lead paint, tinted to suit; but if I had my way the finishing coat should be white-lead, tinted light gray; these tall structures are graceful and ornamental, at least to the engineer's eye, and should be made attractive in color as they are always projected against the sky; they naturally keep clean, and should look well. Tall standpipes present much the same kind of a problem.

This plan involves unusually thin coats of elastic paint; the really right way to handle it is to paint it as suggested, and after one or two years give it about two more coats of the same sort. By that time that which was first applied would be thoroughly hard, and no rust is likely to have started; and with two more coats it would be a good job.

Ship Painting

Ships are generally painted with red-lead; formerly it was the practice to apply three coats, the outer being mixed with white-lead or white zinc; and the paint lasted well even on the under-water surface. Some ships and yachts are now thus painted, but the Navy practise is to apply one coat of heavy red-lead paint containing, aside from volatile ingredients, to a gallon of oil about 32 pounds of red-lead pigment containing not less than 94 per cent Pb_3O_4, or if red-lead paste is the base, not less than 97 per cent of Pb_3O_4. Over this is applied, above water, a lead-and-zinc paint, and under water a coat of very hard quick-drying varnish paint, and outside of this a similar varnish paint containing a considerable amount of oxide of mercury, the poisonous effect of which hinders the growth of various marine plants and animals which would otherwise be attached to the ship's bottom. The latter two coats of paint are supposed to be renewed every six months.

Unless the red-lead (or any other) oil paint is thoroughly dry and hard before being put in the water it will be softened by continuous soaking, so as to be easily scraped off, even though it may still be affording protection against rust. But it will not be thus softened by water if it has become perfectly dry and hard; and as it takes a year or more to build a large ship, I am strongly of the opinion that the best practise would be to apply a coat of red-lead such as has been recently used on the Louisville bridge, made with 67 pounds of paste red-lead and a gallon of genuine kettle-boiled linseed oil; it would pay the shipyard to have a kettle and boil their own oil if that is the only way to get it; this paint should be put on as soon as the outer bottomplates are in place. After this has become thoroughly dry and hard a second similar coat should be put on the under-water part, but above the water-line the amount of red-lead paste should be reduced to, say, 58 pounds to a gallon of oil; this should be allowed time to become thoroughly dry; then a third coat, the same for the bottom, but only 50 pounds of paste to the gallon; and I think for this last above-water portion I should prefer half boiled and half raw oil. Sixty-seven pounds of paste to a gallon of oil corresponds to about 40 pounds of pigment to a gallon; 58 pounds to about 36 or 37 pounds of dry red-lead to a gallon, and 50 pounds to 33 to a gallon of oil. These high proportions would be impracticable with red-lead of less than 97 or 98 per cent Pb_3O_4; but it seems to me that the results obtained by the engineers of the Massachusetts water supply commission, and the forty-six years' test on the old Louisville bridge, justify such practise, which, moreover, agrees with the author's long experience.

I am certain that any bridge engineer will agree that a ship—which is a steel structure—painted as described would be well painted; and it would be reasonably sure to remain in good condition for many years. It may be true that the best of paint will get scraped off; but the surface actually bared in this way is a small proportion of the total surface, and if this is promptly and carefully spot-painted with a red-lead paint which has been made quick-drying by a more than usual amount of drier, no serious corrosion should ever occur. Because a ship offers a different problem of protection than a bridge


FIRE-BOAT NEW YORKER
N.Y. CITY
THE GOLD DREDGE "YUBA"
CALIFORNIA
THE WASHINGTON IRVING
HUDSON RIVER N.Y.
THE ROBERT FULTON HUDSON RIVER N.Y.
THE HENDRICK HUDSON HUDSON RIVER N.Y.

is no reason why the constructor should "lie down" and give it up as a hopeless job; a big railroad bridge costs it may be half a million to a million dollars, and the engineer spends much more money on its painting than is here proposed for a ship costing ten millions, or more.

The whole tendency of late years seems to have been to shunt off the responsibility for maintenance from the naval architect on to the captain or the owner. Of course the latter should realize their responsibilities, but it is more weightily true of a ship than of other structures that the one best time for painting is during construction, when it is under shelter, and the metal is new and clean, and time and opportunity are practically unlimited. If a railroad engineer had a big bridge under a roof for a year he would do something to it besides putting on one coat of paint. After the three coats of red-lead as described there should be one coat (above the water-line) of half red- and half white-lead; to 100 pounds of the mixed paste add a gallon and a half of raw oil, a gallon and a half of turpentine, and a pint of drier; then a coat of color over this. These will dry quickly. Some day, I hope, some ships will be painted this way; and when they are the shipyard will cease to be a place besieged by every paint quack from this country and abroad.

It may be said that such elaborate painting is evidently designed for a permanent structure, while a battle-ship becomes obsolete in fifteen or twenty years. It is not designed to be so; and if proper painting will prevent corrosion it will aid greatly in maintaining the speed, which is highly desirable. I have seen a ship-of-war cleaned with sand blast, which revealed rust-pits on the sides, below the water-line, large enough to hold peas; objectionable in themselves and affording hold for marine plants and animals. When premiums were given for speed, the growth of such things on the bottom of a new ship in two weeks was enough to cost the builders a hundred thousand dollars. It is likely that for the money spent nothing increases the value of a ship so much as good paint on the bottom. No doubt an anti-fouling paint is also needed, but there should be a smooth, clean surface on which to put it.

Railway Cars and Other Vehicles

Steel railway cars, especially coal-cars and others having the upper or container parts of sheet metal, have often been neglected in the past. Some of the best railways have long painted these with at least one coat of red-lead; but others have allowed the use of very cheap and inferior paints, claiming that any paint is quickly abraded and is of little use. But during the war the impossibility of getting enough cars, and later their high prices, gave new weight to the claims, of those who painted them well, that their cars lasted longer. They certainly do; one never sees a car which has been well painted looking so dilapidated and generally disreputable as those which were neglected in the first place. No doubt dumping coal, or broken stone for concrete, scratches off some of the paint; but does any one stop to think how long it would take to get all the paint off in that way if we wanted to remove it? Especially on the outside; it cannot be done. Small spots of metal may show; but it would take quite a gang of men to clean all the paint off a coal car in a week, with scrapers. Such paint does not flake off; every individual particle has to be scraped off. What destroys a steel car is having the whole surface get rusty, so that it becomes thin in large areas and breaks away. If cars were well painted when new, and repainted once in five or six years, the bodies would last until the running parts wore out. And the running parts, or gear as wagon-builders call them, will repay good painting. The metal parts of street cars generally are so painted, and ought to be always.

This leads to consideration of wagons and, especially, automobiles. It is not uncommon to see paint scale off in large flakes; it needs a good priming coat to stick to smooth metal, especially if the latter is subject to vibration and shock. The hard varnish, often baked on, which is the outside finish, tends to crack and pull off the undercoat, and the latter should be such as will adhere to the metal with the greatest obstinacy and it is generally conceded that nothing equals red-lead in this respect. It may be used, if so wished, with a spraying-machine; the Navy Department painters have painted the outside of ships in this way, using exactly the same mixture as for the brush. Formerly this was thought impossible, and there are now some machines which will spray only thin paints, but with the proper device lead paints can be sprayed. But most people prefer the brush. At least two coats of red-lead should be used, so as to get a good, solid film; the car painter often finishes with a coat of cheap black paint, to show up the lettering which is done with white-lead, no other white paint being sufficiently opaque; but it would do the railway men good to consider the practice of the builders of farm wagons. It is important, as a matter of advertising to the wagon-builders, to have these remain well painted as long as possible; hence they use as good paint as they can get for the finishing coat, and it lasts well. Why not paint cars on this plan; if the finishing coat lasts, and the undercoats do not come off, the owner will be the gainer. Cars are going to cost more money than they have in the past, and it will be a more serious thing to let them be destroyed by neglect. There is no more sense in it than there would be in neglecting to paint a bridge.

How to Test Red-Lead Paint

Inspection of red-lead paint by weight is very easy and the inspector should know how to do it. A gallon of water weighs 8.33 pounds; hence any pail which holds that amount of water may be used as a gallon measure. A table appended to this book gives the weight per gallon of practically every sort of red-lead paint. The inspector can weigh a gallon of it on any ordinary scale to an accuracy of 1 per cent which would be about a quarter of a pound, which tells at once if it is near the specification. A gallon of good red-lead paint weighs over 23 pounds.

It takes but a few minutes to make a test, anywhere. A fair sample must be taken. As red-lead is the heaviest pigment, any adulteration will show lessening of weight. This is in fact an argument in favor of red-lead—it is so easy to inspect; and a similar reason may be urged for using paste red-lead, 100 pounds of which measures but 2⅛ gallons and is the smallest 100-pound package ever seen in the paint trade; an adulterated material requires a package so much larger as to be easily noticed; and the pigment must contain at least 97 per cent Pb_3O_4 or it would harden in the container, and the maker would not venture to put it up; and it must be fine, because it cannot be oxidized to 97 per cent unless it is extremely and uniformly so.

The only thing to test is the oil, a sample of which may be dissolved out with ether. If it smells and dries like linseed oil it is pretty sure to be linseed oil; the only adulteration the writer has met with in oil in paste red-lead is a fish-oil soap, which has an evil odor, and the extracted oil does not dry properly. So the only test necessary requires no laboratory or much apparatus, or any training, more than any young engineer may be expected to have.

Advantages of Paste Red-Lead

Dry red-lead is not so easy to distinguish; its weight per cubic inch may vary 100 per cent and adulteration may be difficult to determine. But the more important reasons for using paste red-lead are its fineness, smoothness and ease of working, uniform thickness of film and consequent economy, and its sanitary advantage; as it is free from dust it never causes lead poisoning.

Sanitation

The class of workmen who generally use red-lead are not aware of the danger from the dry powder, which is appreciable, and their employers should take all expedient precautions for their protection. This is not an individual fad of the writer; white-lead, formerly used dry, is now almost exclusively sold as paste; some large and important paint manufacturers, as Masury & Co., and the Lowe Bros. Co. (others might be named), will not use it dry because of the danger to their employees; a single one of the numerous lead-products makers has spent more than two hundred thousand dollars in protecting the workmen from such dust; and certainly the buyers of red-lead, some of whom buy a hundred tons at a time, may be invited to give the matter a little consideration.

Lower part, rust lumps, or "tubercles"; $\times \frac{1}{8}$. Above, part of the same surface, sand-blasted, showing pitting

Need of Cleaning

This book is primarily about red-lead painting; but no book should ever be written about painting on metal without saying something about cleaning the metal surface; this is the foundation, and the source of most of our troubles. Any decent paint on a perfectly good surface will outlast the best possible paint on a poor one. That is, paint is not fool-proof.

The fundamental proposition is that paint sticks to iron in the same way that other things do. We know how other things do. Thus: if the electroplater wishes to deposit copper or nickel on iron, he cleans it first; scrapes off any coarse dirt, then puts it in an acid bath and cleans off all dirt, oxide and scale, leaving the metal with its own gray-white color to be seen in all parts. Then he expects to be able to secure perfect adhesion of his coating. Those who apply vitreous glazes, as with graniteware and the like, do the same thing; and varnish enamels require the same surface. In all these cases it is perfectly well known that no dirt nor grease nor intermediate film of any kind may be allowed between the actual metallic surface and the coating; otherwise the latter will crack and peel off. Paint is softer and tougher and does not crack so easily; and it yields more to expansion and contraction from changes of temperature. Sometimes it protects the film of scale so that the latter does not come off as easily as it otherwise would, and in this way it remains in place and protects the metal beneath; but perfect adhesion is possible only where it touches the bare metal. The only common method of getting this condition is by using the sand blast.

Sand Blast

The writer was the first to use this method on structural metal (see Engineering News, Sept. 23, 1897, or Engineering Record, Sept. 25, 1897), which has now come into common use; though I suppose not more than 1 per cent of all structural steel is ever cleaned in this way even now. Several railroad companies have sand-blast plants mounted on cars for cleaning bridges in place; and it would be an excellent investment if every state highway commission had one mounted on a truck which could be shipped by rail to a convenient point and then hauled to the bridge; as the railway companies are heavy tax-payers they might be willing to give free transportation. Sand, which is sometimes the chief item of expense, is generally cheap in the country. I have known a railway company to furnish men and apparatus to sand-blast highway bridges for the mere cost of labor of the men employed. Highway engineers should always cultivate the friendship of the railroad men; both will be gainers by it.

The details of this method are so well known that it is not worth while to describe them, and information may be had from the numerous makers of machines who advertise in the engineering papers. In a general way it may be said that the tendency seems to be to use higher air pressure and smaller hose than formerly, 80- and even 100-pound pressure per square inch being often used; high pressure is necessary to cut away hard scale. The cost seems to be from two to five cents per square foot, varying with cost of sand, staging, cleaning up of debris, and the size of the job. The nozzle-men should always wear dust-proof helmets, as the powdered sand is very injurious to the lungs. It should never be used in a confined space unless so situated that it may be constantly swept by an abundant current of air; otherwise the paint dust may cause harm.

Pickling

Metal surfaces may also be cleaned by pickling, which is by immersing them in a dilute acid—commonly sulphuric—until the scale has dissolved or has fallen off because the acid has penetrated beneath it. This process was used for cleaning the anchorage of the old Brooklyn Bridge; and the steel underfloor of the Williamsburg Bridge; also for pipes to be enameled, for United States ships; but otherwise it has been used little or not at all on structural material in this country. It has long been used in England and Europe on bridge material and the like. It is said by experts of the Western

Electric Company, which does great quantities of enameling, that it produces a better surface than the sand blast. The pickled surface is full of sharp points, holes, ridges and furrows, to which the coating adheres; while the sand-blasted surface is smooth, the prominences and depressions being rounded, smooth, and possibly slippery.

Before pickling the pieces are soaked in hot 10 per cent caustic soda solution, to remove grease and dirt, then washed and put in the dilute acid which sometimes—perhaps usually—is about 10 per cent acid; it is kept hot by blowing steam into it. It is left in this until the whole surface is clean; the time will depend on its condition. It is also good practise to use stronger acid, 20 to 28 per cent, also hot, which will clean the metal in five to ten minutes. It is not absolutely necessary to use the preliminary alkali bath; but it has the effect of keeping the acid bath cleaner.

On removal from the bath the acid must be removed. This may be done in any of several ways. In some large plants the metal is washed in boiling water, then in 10 per cent carbonate of soda solution, then again in hot water. If the metal is first put into cold water from the acid a gummy, colloidal basic sulphate is formed, difficult to remove; but it may be washed with a jet of water from a hose, at a pressure of not less than 100 pounds per square inch, which mechanically cleans the surface. Others practise putting it from the acid into hot milk of lime (made by stirring freshly slacked lime in water) and after removing it let it dry, and before painting brush off the lime dust. This is a simple and excellent way, the more so as iron thus treated is not likely to rust until the lime is brushed off. The cost of pickling moderately heavy structural shapes is probably about $1.00 a ton; but little is accurately known about this part of it, in this country.

Scraping and Wire-brushing

Comparatively little structural metal is cleaned by such thorough methods as have been described; the next best way is by scraping and wire-brushing. The wire brush alone is not good for much but it is good to clean off loose dirt. Sometimes it is necessary to use a hammer and chisel to get off thick and closely-adherent scale; but scrapers are usually depended on; these are strongly made of tool steel, often with substantial wooden handles; of various sizes and widths, so as to get into recesses. Some are bent at right angles near the end and are used like a hoe.

Mill-scale

In any case it is necessary in some way to get rid of rust. The closely adherent blue mill-scale is anhydrous, and in itself is not so bad; it is true that in the presence of acid or perhaps water it acts as an electrode, setting up chemical action; but the universal experience of practical painters is that closely adherent clean blue mill-scale does not cause trouble if well painted. This is regarded as rank heresy and impossible by some of the more unbending theorists, but if it is true it is probably because it ought to be so. The writer has seen, after removal of the paint, sound and continuous blue scale on sheets of iron (pipe) which had been buried in clay for twenty years. Nevertheless, it is safer to get it off if it will come off; any scale which is at all loose is dangerous.

Rust Is Persistent and Obstinate

It is well known to most people that iron exists in nature chiefly as oxide; sometimes it occurs in meteorites (perhaps only there) in the metallic state; but practically all terrestrial iron is in chemical combination. To extract the oxygen from the oxide we mix it with coke or charcoal, and in the intense white heat of the blast furnace the carbon, in a gaseous form, burns out the oxygen, and the iron runs out as a liquid. But nature is always trying to get it back into an oxide, and sooner or later this will come to pass; all we can do is to retard the process as much as we can, which is by keeping oxygen away from it with paint, concrete, and similar means. The oxide may be anhydrous, as hematite, magnetite, or the blue scale formed in the

Rust on a neglected highway bridge

rolling-mill; or, more commonly, hydrate, as the mineral limonite, or as common rust. This cannot be dehydrated, in the chemical sense, except by a protracted red heat; though free absorbed moisture may probably be driven out by a somewhat prolonged use of the painter's torch. Rust is an obstinate and obnoxious thing; even when it looks dry it generally holds moisture, and the moisture holds carbonic acid; these act on the metal and make more rust, which swells and makes cracks in the paint, and from the air the supply of oxygen is renewed; so it is that "rust doth corrupt." It is not to be tolerated.

Smeaton, of whom James Watt said that "his example and precepts have made us all engineers," said he "had observed that when iron once gets rust, so as to form a scale, whatever coat of paint or varnish is put on over this, the rust will go on progressively under the paint." The following century and a half of observation has made no change in the truth of this, which is only confirmed by longer experience. Not that paint does no good unless applied to a perfect surface; if it is a good paint it obstructs and retards the entrance of air and moisture; but it is important to get as clean metal as possible. The difficulty of doing this gives rise to all sorts of illusions; it has already been told how scientific terms have been misused in this way; and all kinds of extravagant claims are persistently and persuasively urged. Only the other day (so to speak), a well-known engineer in responsible charge of an important bridge, applied to it a certain paint which, he said, experience for several years had shown to "absorb the oxygen from rust"; as the chief chemist of one of the big steel companies said, "thus doing away with the blast furnace." Another chemist suggested that it was a new catalyzer; still another (a paint chemist) that the salesman was a psychologic catalyst, the exuberance and vitality of whose fancy delights and deludes those who have never lived in his world of imagination.

Brushes

Good painting requires good brushes. Most painters advise the use of what is called a pound brush; the bristles when new are about six inches long, and the shape is cylindrical. Bristles of this length are too flexible; so it is customary to "bridle" the brush, which is to confine it so that only the tip of it is used, the part nearer the handle being tied so as to be a solid mass. This is done in various ways: a bridle may be bought from the brush-maker; or, with a long cord, the brush may be wound from a suitable place, say 2 or 2½ inches from the binding, to completely bind the brush to where the brush-maker's binding begins; or a strip of cloth, about 8 inches wide, may be wrapped around the brush and securely tied to the binding. Then with another piece of cord tie it around the bristles, say 4 inches from the end of the bristles and 2 inches from the binding; then turn back the cloth, like a sleeve turned half inside out, and tie it again around the binding. Trim it off, and the bridle is done. As the bristles wear off the bridle may be moved up, and finally removed. But do not buy a new brush with a bridle on it; take it off and see that the bristles are elastic and strong; soft flabby bristles do not make a good brush.

A new bristle naturally terminates with what is sometimes called a feather; split up, as it were, into fibers. These hold the paint; and there should be shorter bristles, with these ends, all through the brush, so that as it wears off it will still have this necessary quality. The object of binding is to prevent the brush from being too soft, and spreading like a mop; it is supposed to rub the paint into the rough surface of the iron, and to rub out the air film which adheres to the surface; air, and probably an invisible coat of moisture, adhere strongly to a metal surface. This is one reason why many prefer the brush to the spraying-machine.

If flat brushes are used they should not be more than 4 inches wide, or 5 at the most, for metal painting; and they should be good thick brushes, of good material. Using a wider brush it is impossible to rub out the paint properly.

Brushes used in oil paints may be kept fresh and clean overnight, or while carrying them from place to place, by wrapping them closely in several thicknesses of paper; it is better if the inner layer of paper be wet with water.

When through with a job they may be well washed out with kerosene, and then well rinsed with gasoline, and hung up to dry where they will be free from dust.

Brushes which are worn short, so as to be stiff and stubby, are very desirable for rubbing paint on to metal which has been rusty and is rough, and for similar uses. For this reason brushes should be kept clean and carefully preserved. The best brushes are the cheapest in the end, and a valuable brush deserves good care. Never let one dry with the paint in it.

Paint Calculations

Linseed oil is usually considered to weigh 7.76 pounds per measured gallon (231 cu. in.) which corresponds to a density of .931, and turpentine is supposed to weigh 7.1 to 7.2 pounds, or to have a density of about .86. Commercial (petroleum) benzine weighs about 6.2 pounds per gallon, but is variable. A gallon of water at ordinary temperature weighs about 8.33 pounds and this is the important figure to remember. If we multiply this number, 8.33 by 6.6, which is the density of white-lead, we have 55 pounds, which is the amount of dry white-lead required to make a gallon; that is, if we thoroughly mix 55 pounds of dry white-lead with a gallon of oil, so as to drive all the air out of the interstices of the powder and replace it with oil, we shall have exactly two gallons of a mixture which would be in fluidity intermediate between paste white-lead and a paint; but if we mix this 55 pounds of dry white-lead with 3 gallons of oil, we shall have 4 gallons of white-lead paint. In the same way we may find out the weight of any pigment required to make up the volume of a gallon (when wetted with oil or other vehicle), by multiplying 8.33 pounds by the figures indicating the density of the pigment in question. Thus, the density of lampblack is 1.82 and if we multiply 8.33 pounds by 1.82 we have 15 pounds, which amount of lampblack mixed with 7 gallons of oil makes 8 gallons of black paint; the density of white zinc is 5.55 and multiplying 8.33 by this we have 46 pounds for the weight of a gallon of dry white zinc, which if mixed with 6 gallons of oil makes 7 gallons of white zinc paint.

Volume Proportion

It will be noticed that to enough pigment to make a gallon we add in the case of white-lead 3 gallons of oil, with lampblack 7 gallons, and with white zinc 6 gallons. There is no rule about this; the amount of oil each pigment takes is found out experimentally; but white-lead (or perhaps barytes) takes the least and lampblack the most of all pigments. The volume of oil is, however, much more simply related to the volume of pigments than to their weights. In general, the pigment constitutes from one-fourth to one-sixth or one-seventh the volume of the paint.

A practical problem of this sort arises in a case like this: red-lead and oil make a paint much used in painting iron and steel; the red-lead and oil are mixed in such proportions as the user desires, according to the character of the work. Thus, 33 pounds pigment to a gallon of oil is used for underwater work; 28 pounds pigment to a gallon for other marine work; 25 pounds or more for bridges, and so on. To find the cost of the paint in each case it is necessary to know not only the cost of materials, but also the volume of paint produced. We find by computation that 72 pounds of red-lead make a gallon; then 33 pounds equals .46 gallon; 28 pounds equals .38 gallon; 25 pounds equals .35 gallon and so on, and so these mixtures will amount to 1.46 gallons, 1.39 gallons, 1.35 gallons, and so on. Multiplying the number of pounds of dry pigment by the price per pound and adding the cost of a gallon of oil gives us the cost of materials of each of these various amounts, from which the gallon prices may be computed; and in no other way can it be done.

Here is another case: Suppose the analysis of a paint shows 80 per cent white-lead and 20 per cent asbestine, by weight, in the pigment, and that the consistency of the paint is such that it corresponds to a white-lead paint mixed up in the proportions


PITTSBURGH S.S. CO'S. WILLIAM E. COREY.
GREAT LAKES S.S. CO'S "HARRY COULBY"
PIONEER S.S. CO'S "ONTARIO"
D.&B. S.S. CO'S "EASTERN STATES"

of one volume of dry white-lead to three volumes of oil, which is common. We know that 92 pounds dry white-lead requires 8 pounds oil to make a paste; and we also know that a given volume of asbestine paste contains twice as much oil as the same volume of white-lead paste. It takes, we find, 55 pounds dry white-lead to make a gallon, and one-quarter of this, 14.25 pounds, mixed with three-fourths of a gallon (5.81 pounds) of linseed oil makes a gallon of paint. If 92 pounds white-lead take 8 pounds oil for a paste, 14.25 pounds will take 1.24 pounds (.16 gallon) oil to make a paste and the rest of the 5.81 pounds or 4.55 pounds (.59 gallon) is used for thinning the paste, the volume of which is .41 gallon. Practically, we are taking one and a half volumes of oil to one volume of paste, and we may assume (though it is not strictly accurate) that this rule will apply to all pastes of similar consistency.

A Sample Problem

We find by computation that 23 pounds dry asbestine make a gallon; and to find the composition of a gallon of asbestine paint we may proceed as follows: If 92 pounds white-lead and 8 pounds oil make a paste, an amount of asbestine corresponding to 84 pounds of white-lead requires 16 pounds of oil (2.06 gallons). Eighty-four pounds white-lead equals 1.53 gallons and 1.53 gallons asbestine equals 35.2 pounds, making a total of 3.636 gallons. This is asbestine paste; to make this into paint we add (3.63×1½) equals 5.45 gallons oil, making 9.1 gallons paint, composed of 35.2 pounds asbestine, and 2.06+5.45 equals 7.51 gallons oil; and 1 gallon contains .83 gallon oil and 3.86 pounds asbestine. If white-lead costs 14 cents and asbestine 1½ cents per pound, and oil $1 per gallon (which are usual prices) the white-lead paint will cost $2.75 per gallon and the asbestine paint 89 cents per gallon.

Going back to our original analyzed paint, it contains 80 pounds of dry white-lead to 20 pounds of asbestine. If 1 gallon of white-lead paint contains 14½ pounds dry white-lead, 80 pounds will make 5.61 gallons, and 20 pounds asbestine will make 5.44 gallons or 11.05 gallons altogether; or a gallon contains 51 per cent of white-lead paint and 49 per cent of asbestine paint, instead of 80 and 20 as might at first sight be thought, and the cost will be $1.83 per gallon, instead of $2.63.

We are liable to deceive ourselves as to the value of such mixtures unless we bear these principles in mind.

Similar methods may be used for paints containing three or more pigments.

Calculations of paint materials are based primarily on weight. The liquids used are lighter than water; some of them considerably so; the pigments are all heavier and differ much. The following table gives the specific gravity of the more important ones; and the use of second column of figures is explained in the preceding text.

SPECIFIC GRAVITY

WEIGHT REQUIRED TO MAKE A GALLON

	Specific Gravity.	Weight Required to Make a Gallon.
Litharge	9.3	77.5
Red-lead	8.4 to 8.8	72.
Orange mineral (orange lead)	8.6 to 8.7	73.
White-lead	6.6	55.
Basic lead sulphate	6.4	53.3
Chrome yellow (medium)	5.8	48.3
Zinc oxide (white zinc)	5.55	46.23
Basic lead chromate	6.8	56.6
English (mercury) vermilion	8.2	68.3
Bright red oxide of iron	5.26	43.8
Indian red oxide of iron	5.26	43.8
Brown oxide of iron (Prince's)	3.2	26.6
Ultramarine	2.4	20.
Prussian blue	1.95	16.2
Chrome green, blue tone	4.44	37.
Chrome green, yellow tone	4.0	33.
Lithopone	4.25	35.4
Ocher	2.94	24.5
Barytes	4.23 to 4.46	35 to 37
Blanc fixe	4.25	35.4
Gypsum (terra alba)	2.3	19.
Asbestine (magnesium silicate)	2.75	23.
China clay (aluminum silicate)	2.6 to 2.7	22.5
Whiting	2.65	22.
Silica	2.65	22.
Natural graphite	2.6	21.6
Acheson's graphite	2.2	18.3
Lampblack	1.85	15.4
Carbon-black	1.85	15.4
Keystone filler (ground slate)	2.66	22

To this table the following data may be added: The weight of one gallon of paste with

Red-lead	47.	pounds
White-lead	35.6	"
White zinc	25.	"
Chrome yellow (medium)	30.	"
Chrome green	24.	"
Venetian red	19.	"
French ocher	13.6	"
Prussian blue	10.	"
Lampblack	9.25	"

A gallon of most paint pastes takes about $1^{1}/_{6}$ gallons of oil to make a paint. One thousand pounds of white zinc paste plus 878 gallons raw oil and 3 gallons drier makes 130 gallons paint. White zinc paste therefore takes much more oil than most paste; and in fact these figures are for rather stiff pastes, and there is no close uniformity in the amount of oil they take; moreover, diffrent painters use paints of different degrees of viscosity; so that these statements as to pastes are suggestions rather than formulas. As such the writer finds them useful memoranda.

The chrome yellows vary; orange chrome has more lead in it, which makes it heavier than medium chrome yellow, and lemon chrome has sulphate of lead in it (to make it paler), which also makes it heavier. The density of red-lead is variable; in general the higher the percentage of Pb_3O_4 the lower is the density; but this is also influenced by the temperature of making it and the material from which it is made; in general, crystals are heavier than amorphous bodies. The density of litharge varies from 9.25 to 9.52; some of it is crystallized from a fused condition. Orange mineral is red-lead made by roasting white-lead, and while some of it contains considerable PbO and is correspondingly heavy, some of it has as little as .25 per cent PbO and may have a density of only 8.35.

Thoroughness

The following specifications are offered for general new work. In an appendix will be found a concise set of specifications for miscellaneous use; for while this book is primarily intended to give information rather than advice, it is impossible to resist the temptation to mix the two. No doubt most people will think the ideas thus set forth as to painting are extreme in the matter of attention to detail, and in expense; I hope so, for I would not willingly contribute anything to the subject which should not urge an improvement in current practise, while on the other hand there is nothing prescribed which I have not seen done, in one form or another, many times. It is now about a quarter of a century since I published my first general specifications for structural painting, and it is good to be able to say that such practise is now far more common, and the average of such work is considerably higher, than it was then; it would be foolish to think that this is due in any great measure to the influence of any one man, but every intelligent discussion of it helps to create and sustain its interest among structural engineers in general, the only source from which we may look for improvement. By a steadily increasing number of interested experts these methods are ceasing to be regarded as academic; and while methods are, within certain limits, more important than material, it is time to insist on more study of the latter. During the last fifteen years most of the author's writings have been on the subject of materials for paint and varnish; if methods of application can be standardized, excellence and economy in results depend on using the right material in its own proper place. For more than a hundred years red-lead has occupied an important place in public estimation; now more than ever, in protection of structural metal, it easily heads the list.

Specifications

Shop painting: The metal shall be cleaned so as to be free from dirt, rust and loose scale; this shall be done, if necessary, by thorough scraping and wire-brushing; grease shall be removed by a cloth wet with benzine. Surfaces to be riveted shall receive a full coat of heavy red-lead paint. The metal shall be painted with a full smooth coat of paint made as follows: To 100 pounds of paste red-lead shall be added 2½ gallons of linseed oil, making 4.6 gallons of paint; or, if dry red-lead is used, to each gallon of oil 28 pounds of dry red-lead shall be added, making 1.4 gallons of paint. To each gallon of this may be added at the discretion of either the master-painter or the inspector not more than one-third of a pint of drier; also, if thought best one-third of a pint of mineral turpentine.

Striping Coat

Second coat: After erection, dirt and grease shall be removed; all places not well covered with paint shall be repainted, all rivet and bolt heads shall be painted, all edges shall receive a striping coat extending an inch from the edge; and when this paint is dry one full coat of paint shall be applied over the whole surface. This paint shall be made as follows: To 100 pounds of paste red-lead shall be added ¾ pound of paste lampblack and 2⅝ gallons of linseed oil, making 4⁴/₅ gallons of paint; or, to each gallon of oil 27 pounds of dry red-lead and 2½ ounces of paste lampblack shall be added, making 1.45 gallons of paint; to this drier and turpentine may be added as for the shop coat.

Third coat: This shall be of paint made as follows: To 100 pounds of paste red-lead shall be added 6 pounds paste lampblack and 3.25 gallons of linseed oil, making 5.6 gallons of paint; or, to each gallon of linseed oil add 23 pounds of dry red-lead and 1.5 pounds of paste lampblack, making 1.5 gallons of paint; and drier and turpentine as before. (This last is about the same as adding 26 pounds dry red-lead to a gallon of oil, and then adding ¹/₆ gallon of lampblack paint, with drier and turpentine.) For use in a dry climate the proportion of oil in the last coat may be increased one-tenth or a little more.

It is to be remembered that because paste lampblack is four-fifths oil it tends to make the film softer and more elastic. It is desirable to have outer coats more so than those beneath, so that weather exposure will finally bring them all to about the same hardness. But not so for underwater paints.

All outdoor painting shall be done in fair weather, temperature not below 50° Fahrenheit.

Quality of Materials

The paste red-lead shall contain from 6 to 7½ per cent of linseed oil; shall contain only pure linseed oil and red-lead analyzing 97 per cent (or more) Pb_3O_4; dry red-lead shall analyze 94 per cent (or more) Pb_3O_4; the oil shall be pure linseed oil agreeing with the specifications of the American Society for Testing Materials, shall be aged at least one month, and a sample after standing twenty-four hours in a graduated cylinder at a temperature of not less than 70° Fahrenheit shall not show more than 1½ per cent of sediment, by volume.

Drier and Turpentine

The drier shall be a light-colored drier, shall be guaranteed free from rosin, and to contain both lead and manganese, the proportion of lead not less than three times that of manganese. Raw linseed oil to which 10 per cent of this drier has been added shall make a film on glass which will be dry to the touch after 12 hours' drying at 60° Fahrenheit, indoors, in moderately dry weather.

A rosin-free drier may always be obtained on orders of considerable size, and is safer and probably better than the more common driers which contain rosin; when oil is high it is a little more costly. There is some doubt as to whether a small amount of combined rosin is harmful, and probably most of the rosin-containing driers sent out from factories of first-class reputation are satisfactory. A large amount of rosin is objectionable, and it is difficult to tell by analysis how much is present if any is permitted. Too much drier lessens durability. Sometimes formulas are seen calling for large proportions—10 to 25 per cent—of drier, or "japan drier"; in these paints the drier is not put in for its usual purpose, but to make the paint take a quick, almost instantaneous initial set, so that it may not "run." This is done for several reasons; and especially with coarse pigments; but always when you see a very large proportion of japan drier used, it is for some special purpose, and not as an ordinary catalyzer. Drier is a thinner, the same as turpentine.

In metal painting turpentine may almost always be replaced by "mineral turpentine," as has been explained elsewhere.

Notes on the Foregoing Specifications

The United States Navy specification for paste red-lead, before the war interfered with the supply, was essentially as follows:

Guaranty

The paste shall be of high-grade quality, free from all adulterants, and the pigment shall show on analysis not less than 97 per cent of true red-lead (Pb_3O_4); shall be equal to the standard sample in freedom from vitrified particles and in other respects; shall be guaranteed against hardening in the original container if kept sealed at ordinary temperature for a period of three months.

A somewhat simpler specification would be: The paste shall contain only red-lead and 6 to 7 per cent of linseed oil and shall be guaranteed for three months against hardening if kept sealed in the original package at ordinary temperature.

If the pigment and oil are pure, the former will have to be 97 per cent Pb_3O_4 or it will harden; if it is 97 per cent it will have to be fine, and right every way.

Oil

The specification for linseed oil is the best known, and should be satisfactory. That for drier is not so definite, but will be easily understood, and should be sufficient. Painters know the difference in color between pale and dark driers. If it is preferred to use boiled oil, it is recommended for ordinary work to use one-third to one-half boiled oil, which should agree with A. S. T. M. specification, and the rest raw oil, and no drier, or very little. The attention of the inspector should be drawn to the fact that when linseed oil is scarce and high in price it is often adulterated; if bought direct from the manufacturer it is reasonably sure to be pure, but there is never any certainty about its freedom from "foots"; if bought two cents a gallon below open market quotations, it must be regarded with suspicion, which at a less price is greatly increased; soon a point is reached where nobody is to be believed except a good testing laboratory.

Dry pigments should never be added to the full amount of oil, but mixed with a little oil to a perfectly wetted paste, and the rest of the oil added, a little at a time, and well stirred in. All pastes are better if passed through a mill.

It is the practise of all good painters to strain all liquid paints, which have been standing more than a day or so, through cheese-cloth, or at least through a sieve.

Heavier paint, that is, containing more red-lead, may be used throughout and would doubtless be better.

It is of course understood that if the engineer feels at liberty to specify sand-blasting or pickling, he will do so.

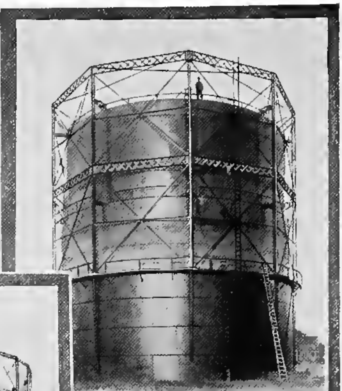
Area Covered

The steel viaduct of the Nickel Plate Railroad in South Chicago is of very heavy plate girders, and a gallon of heavy red-lead paint covered twenty tons with one coat; this was the average of the whole bridge. The same road has bridges which, because of lighter structure, take seven times as much paint per ton. If on the same road the paint per ton varies 600 per cent, it is obvious that tonnage is not a good basis for estimating the amount of paint required. We paint surface and not tonnage.

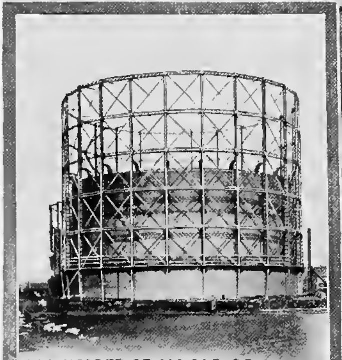
As to the area which a gallon of paint will cover much might be said, because widely different results are obtained by different painters. Contractors' painters are likely to spread it over as much surface as they can; and the regular painting team of a railroad may be trained to put on as full a coat as they can. Also a smooth surface, like a large water tank, or a gas-holder, takes a uniform coat which is therefore spread over more area than the irregularities of a latticed girder. Further, the surface of bridge-work is not easily computed.

The following figures are for paint made from paste red-lead:

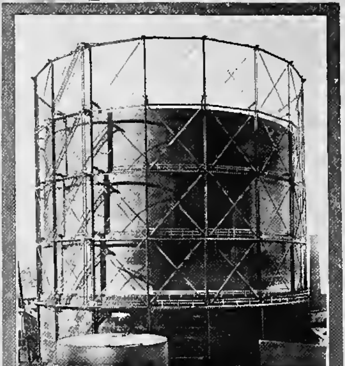
The Long Island Railroad engineers have an excellent painter who believes in full coats; they report a gallon of red-lead paint covers 650 square feet. The United Gas Company of Philadelphia use a heavy paint and on gas-holders covers 900



GAS-HOLDER OF AM. PUB. UTILITIES CO. HOLLAND. MICH.



GAS-HOLDER OF AM. GAS CO. PHILADELPHIA



GAS-HOLDER OF NEW BEDFORD GAS CO. NEW BEDFORD MASS.

square feet. The contractors for an important Pennsylvania Railroad bridge covered 900 square feet. The Maryland Steel Company report 840 square feet on a new ship's hull, using a heavy paint; they had never covered more than 600 square feet with a similar paint made from dry red-lead. The engineers of the Massachusetts water commission report 700 square feet on large tanks, using paint made from 100 pounds paste red-lead to 2 gallons oil (equivalent 33 pounds dry red-lead to 1 gallon oil). The master-painter of the Fore River Shipbuilding Company, where more than 200 tons of paste red-lead have been used, reports that it covers a third more surface than similar paint made from dry red-lead; as this paint is Navy Department formula and the Navy handbook estimates 504 square feet for a gallon made from dry red-lead, this probably corresponds to 700 square feet. The present opinion of the writer, based on such figures as seem reliable, is that such a paint as is advised in these specifications may be expected to cover at least 700 square feet per gallon, with large allowance both ways for differences in conditions. White-lead paint, except in priming coats on wood, often covers more than this. Red- and white-lead have more affinity for oil than other paints, and if finely ground cover more surface than most—perhaps all—other pigments. Any good paint on a smooth hard surface can be brushed out to cover 1500 square feet, but such a film is too thin to be of service,

Spreading Capacity

The quantity of paint required to coat a given number of tons of structural steel in a bridge, building, or similar structure is determined by the area of the surface to be covered and the spreading capacity of the paint to be used. The spreading capacity varies greatly with different paints, but in the case of red-lead it varies with the fineness of the pigment, its freedom from sandy lead, its specific gravity, the consistency of the paint after the vehicle and pigment are thoroughly mixed, the amount of thinner used, and the amount of brushing out given to the paint on the surface to which it is applied. The condition of the surface has an even greater influence on the amount of paint required than any of the characteristics of the paint itself mentioned above. On a smooth rolled plate a paint may be spread over fully 50 per cent more area than on a rough, porous, or rusty surface.

The area of the surface to be covered varies greatly with the character of the construction, this variation being independent of the tonnage. A plate girder bridge whose average cross-section is 1 inch thick will have an exposed area to be painted of a little more than 120 square feet per ton of steel, while a heavier girder, averaging 1½ inches in thickness, would have only about 90 square feet of surface per ton. A moderately heavy building framework whose columns, girders, and beams are about

½ inch thick, will present a painting area of about 250 square feet per ton of steel, while that required for a lighter structure whose members have an average thickness of about ¼ inch will be about 500 square feet per ton. A very light lattice structure whose angles and straps will average $^1/_8$ to $^3/_{16}$ inch in thickness will have a superficial area of from 770 to 1000 square feet per ton.

The surface area of structural steel may, therefore, be said to vary between 100 and 1000 square feet per ton, and it is obviously very difficult to formulate any fixed and simple rule for estimating accurately the quantity of red-lead paint required for painting such material.

General rules can, however, be laid down, which when used in conjunction with data on the general character of the structure to be painted will give a reasonably close estimate of the amount of paint required.

It may safely be stated that a pure red-lead paint, mixed in the proportion of 28 pounds of dry red-lead to 1 gallon of pure linseed oil, without turpentine or other thinner, when applied to average new structural steel surfaces will cover from 600 to 700 square feet per gallon for the first coat, from 700 to 800 square feet for the second coat, and from 800 to 900 square feet for the third coat. By combining these fiugures we find that for two-coat work —that is, for the first two coats, the shop coat and the first field coat—1 gallon of paint will cover from 300 to 400 square feet, and for three-coat work 1 gallon will be required for every 225 to 275 square feet.

It is impossible to make anything but very general statements as to the area to be painted on a ton of steel, varying as it does from 100 to 1000 square feet. In order to arrive at the approximate average thickness of the metal or the area of surface per ton, some study of the drawings is necessary. To assist in forming an approximate estimate of the area per ton, Tables 1, 2 and 3 have been prepared. Table 1 shows the superficial area per ton of iron or steel plate for thicknesses ranging from ⅛ to 2 inches, and Tables 2 and 3 give the area per ton of the different shapes commonly used in steel construction. With the aid of these tables and the plans of the structure to be painted the approximate area per ton may be determined.

As an example, assume a heavy plate girder bridge whose members, according to the plans, have an average thickness of 1¼ inches. By referring to Table 1 we find that this thickness of metal has an area of 80 square feet per ton. Allowing about 10 per cent for edges, rivet heads, and other irregularities, which in the case of such heavy construction is a very liberal allowance, we have an area of 88 square feet per ton. With such conditions a first or primary coat would require about $^1/_7$ gallon per ton. For two coats ¼ gallon would be required, and ⅜ gallons for three coats.

As another example, assume the structure to be a building frame with columns, girders, and beams.

TABLE 1

AREA OF SURFACE OF PLATE PER TON

Based on Iron Weighing 480 lbs. per Cubic Foot

Thickness of Metal, Inches.	Area in Sq. Ft. per Short Ton.	Thickness of Metal, Inches.	Area in Sq. Ft. per Short Ton.
$\frac{1}{8}$	800	1	100
$\frac{3}{16}$	533	$1\frac{1}{8}$	89
$\frac{1}{4}$	400	$1\frac{1}{4}$	80
$\frac{5}{16}$	320	$1\frac{3}{8}$	73
$\frac{3}{8}$	267	$1\frac{1}{2}$	67
$\frac{1}{2}$	200	$1\frac{5}{8}$	62
$\frac{5}{8}$	160	$1\frac{3}{4}$	57
$\frac{3}{4}$	133	$1\frac{7}{8}$	53
$\frac{7}{8}$	114	2	50

TABLE 2

AREA OF SURFACE OF I-BEAMS AND CHANNELS PER TON

Standard and Special I-Beams

Section No. in Cambria Book.	Depth, Inches.	Minimum Pounds per Foot.	Sections, Sq. Ft. per Ton.	Maximum Pounds per Foot.	Sections, Sq Ft. per Ton
Standard					
B 5	3	5.5	422	7.5	317.2
B 9	4	7.5	379	10.5	277.8
B 13	5	9.75	346.8	14.75	235.4
B 17	6	12.25	319.8	17.25	231.2
B 21	7	15.0	294.6	20.0	224.2
B 25	8	18.0	275.3	25.25	199.8
B 29	9	21.0	261.0	35.0	161.0
B 33	10	25.0	244.0	40.0	153.6
B 41	12	31.5	217.8	50.0	173.4
B 53	15	42.0	193.5	60.0	137.4
B 65	18	55.0	171.0	70.0	135.6
B 73	20	65.0	157.0	75.0	136.8
B 89	24	80.0	150.2	100.0	121.0

TABLE 2—*Continued*

Standard and Special I-Beams

Section No. in Cambria Book.	Depth, Inches.	Minimum Pounds per Foot.	Sections, Sq. Ft. per Ton.	Maximum Pounds per Foot.	Sections, Sq. Ft. per Ton.
Special					
B 105	12	40.0	181.7	55.0	134.3
B 109	15	60.0	139.0	80.0	105.8
B 113	15	80.0	105.8	100.0	85.9
B 121	20	80.0	132.7	100.0	107.0

Standard and Special Channels

Standard					
C 5	3	4.0	447	6.00	303.0
C 9	4	5.25	424	7.25	313.0
C 13	5	6.5	408	11.50	238.8
C 17	6	8.0	366	15.50	206.9
C 21	7	9.75	361.6	19.75	185.5
C 25	8	11.25	350.8	21.25	191.7
C 29	9	13.25	331.0	25.00	180.4
C 33	10	15.0	321.3	35.00	143.4
C 41	12	20.5	277.2	40.00	146.1
C 53	15	33.0	209.0	55.0	128.3
Special					
C 91	12	21.4	254.8	33.9	163.6
C 95	13	32.0	207.0	55.0	123.6
Special Ship Channels					
C 86	6	15.2	271.0		
C 88	6	19.0	211.2	21.6	148.4
C 89	7	20.9	209.4		
	8				
	9				
C 90	10	21.70	246.2		

TABLE 3

AREAS OF SURFACE OF ANGLES AND Z-BARS PER TON

Standard Angles with Equal and Unequal Legs

Section No. in Cambria Book.	Dimensions, Inches.	Minimum Pounds per Foot.	Sections, Sq. Ft. Per Ton.	Maximum Pounds per Foot.	Sections, Sq. Ft. per Ton.
Standard Equal Legs					
A 5	¾×¾	0.60	790.0	0.69	687.0
A 7	1×1	0.80	732.5	1.50	390.0
A 9	1¼×1¼	1.10	644.5	2.40	295.2
A 11	1½×1½	1.30	746.0	3.90	248.6
A 13	1¾×1¾	2.20	509.0	5.10	219.2
A 15	2×2	2.50	516.0	6.00	214.6
A 17	2½×2½	3.10	523.5	8.50	191.1
A 19	3×3	4.90	396.8	12.50	155.4
A 21	3½×3½	7.20	314.2	18.30	124.6
A 23	4×4	8.20	321.8	21.20	120.4
A 27	6×6	14.90	262.8	37.40	104.7
A 35	8×8	26.40	199.1	56.90	92.4
Standard Unequal Legs					
A 91	2½×2	2.8	519.0	7.6	191.3
A 93	3×2½	4.5	394.6	10.4	170.6
A 95	3½×2½	4.9	396.3	13.4	145.0
A 97	3½×3	6.6	316.0	16.8	130.1
A 99	4×3	7.2	303.8	18.3	119.5
A 101	5×3	8.2	307.4	21.2	118.9
A 103	5×3½	8.7	317.2	24.2	114.0
A 105	6×3½	11.7	262.8	28.9	102.8
A 107	6×4	12.3	261.8	30.6	104.0

TABLE 3—*Continued*

Standard and Special Z-Bars

Section No. in Cambria Book.	Dimensions, Inches.	Minimum Pounds per Foot.	Sections, Sq. Ft. per Ton.	Maximum Pounds per Foot.	Sections, Sq. Ft. per Ton.
Standard					
Z 5	3.0	6.7	384.0	8.4	309.0
Z 9	3.0	9.7	259.6	11.4	231.2
Z 13	3.0	12.5	210.8	14.2	188.4
Z 21	4.0	8.2	377.2	12.4	256.0
Z 25	4.0	13.8	228.8	17.9	181.0
Z 29	4.0	18.9	170.4	23.0	143.8
Z 37	5.0	11.6	304.8	16.4	217.2
Z 41	5.0	17.9	210.0	22.6	162.3
Z 45	5.0	23.7	154.2	28.3	132.3
Z 53	6.0	15.6	257.2	21.0	194.8
Z 57	6.0	22.7	179.5	28.1	147.9
Z 61	6.0	29.3	141.2	34.6	123.0
Special					
Z 67	7.5	16.3	264.6		
Z 73	8.0	22.1	202.4		

If the columns are 10-inches channels of minimum weight, latticed on two sides with $^5/_{16}$-inch straps, such a column would have an area per ton of 321.3 square feet for the channels and 320 square feet for the straps, or the combination might average 320.7 square feet per ton. If the girders are 18-inch maximum-weight I-beams they would have an area of 135.6 square feet per ton, while if the beams are 8-inch 11.25-pound channels, they would have a surface of 350.8 square feet per ton. The whole combination might be judged to average 300 square feet per ton and would therefore require between $^2/_5$ and $^1/_2$ gallon of paint for the first coat, ¾ to 1 gallon per ton for the first two coats, and 1⅛ to 1½ gallons for three coats.

In estimating the cost of paint materials from the data which have been given, it must be remembered that all figures are based on the measured gallon of 231 cubic inches, and that while a gallon of linseed oil weighs 7.75 pounds, the trade has always used a trade gallon of 7½ pounds of linseed oil, and in buying oil in barrels this is what is bought; about 3 per cent more is needed than of measured gallons.

This is what the writer thinks ought to be used; but experience shows that less paint, that is, thinner coats and more spreading with the brush, is the average practise; and that 60 to 70 per cent of these amounts of paint are in more general use.

There is no use in shutting our eyes to facts. There is the compensating consideration that paint must be well brushed out to cover more surface, and this is as important as anything can be.

Since the advent of very high grade (paste) red-lead the writer has carried on systematic inquiries as to painters' practise with it; and while the following general rule must be taken with consideration of the foregoing discussion, it is certainly a convenient thing to have a middle ground from which to look over the situation:

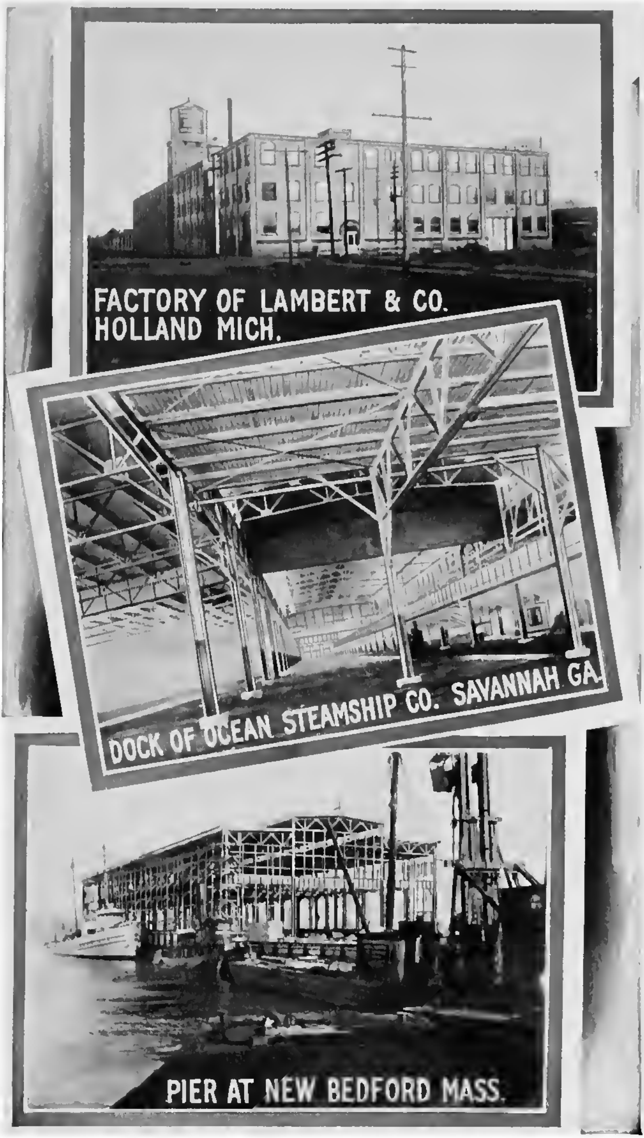
ON MEDIUM WEIGHT BRIDGES, ⅜ GALLON PER TON FOR FIRST COAT; ¼ GALLON FOR SECOND

COAT; ¼ GALLON FOR FINISHING COAT; OR ⅞ GALLON FOR THREE COATS. HEAVIER BRIDGES LESS, AND LIGHTER MORE, PER TON. Roofs 1000 to 1200 square feet per gallon.

As a Paint for Wood

It is generally assumed that white-lead is the best priming coat for wood; but the fact is that there is nothing which will always prove satisfactory. For many years red-lead has been used for this purpose in England; this practise has been introduced into the United States through Canada, and has been growing in favor for at least ten or twelve years, although it cannot be said to have become very extensive. It has already been said (p. 24) that, in general, successive coats of paint should be progressively more elastic; and to make a hard undercoat only a small amount of oil is mixed with the pigment. On the other hand, wood, unlike metal, absorbs oil; hence it is necessary to use considerable oil in the priming coat, or else the oil will all go into the wood and leave the pigment as a dry, non-adhesive coating, not fit to bind the next coat to the wood. But if the wood surface is full of pitch the oil is not readily absorbed; this gives rise to the practise of using with the oil a considerable amount of turpentine, which has a solvent action on the pitch, and makes the absorption more uniform.

For some unknown reason, red-lead is less likely to soften and blister over these pitchy spots than white-lead. The writer formerly supposed that this



FACTORY OF LAMBERT & CO.
HOLLAND MICH.

DOCK OF OCEAN STEAMSHIP CO. SAVANNAH GA.

PIER AT NEW BEDFORD MASS.

might possibly be due to chemical action between the litharge of the red-lead and the resinous matter; but experience shows no difference in behavior between red-leads containing 85 to 98 per cent Pb_3O_4, so that theory has been given up. But it seems to be true that red-lead paint sticks better than white to such surfaces, and that is the practical thing to know. And as red-lead paint is harder than white-lead, and no less tough, it naturally makes a good priming coat for any kind of wood. Its color is against it, if the finish is to be white; two coats of white-lead over it will still show a little red; but two coats of light gray or any corresponding tint will not be considerably, if at all, affected; for the opacity of any tinted paint is much greater than that of white. Half white- and half red-lead for a priming coat may be used, even if the finish is to be white.

A good priming coat for yellow pine and the like is as follows:

100	pounds paste red-lead.
1¾	gallons raw linseed oil.
1¾	gallons turpentine.
¼	gallon drier.
6	gallons of paint.

Or for white pine, white wood, or poplar:

100	pounds paste red-lead.
4½	gallons raw linseed oil.
½	gallon turpentine.
¼	gallon drier.
7½	gallons of paint.

A skillful English painter, of long experience, recently wrote to the author, urging more extended descriptions of the use of red-lead in house-painting, especially for interiors, as "it gives a splendid foundation upon which to build the succeeding coats of paint, without the necessity of shellacking. The red color is of no consequence, as three coats are usually given on interior surfaces anyway."

There is no doubt that architects should be more familiar with its use on metal roofs, and especially on valleys, gutters and down-spouts; and on metal railings, which are particularly troublesome to clean if they ever become rusty, because of their irregular and intricate forms. The architect should also be particular to advise frequently repainting of valleys in roofs, and it is in these that leaks most frequently start, causing much damage. The thorough painting of all exposed metal work about buildings is of importance, because its renewal is so expensive, not merely because of the cost of material but still more from the inconvenience and excessive labor cost of replacement.

The appreciation of these things has led the author to include, among the specifications in the appendix, some for the architect's guidance.

APPENDIX I

Analytical Method

At the 1917 meeting of the American Society for Testing Materials, a method for testing red-lead was adopted as standard. This is herewith given. The same method has long been in use in the laboratory of the National Lead Company, and their statement of it is added, with the thought that by comparison any step which may seem obscure to the inexperienced analyst may be made more clear.

It should be observed that the analysis of paste red-lead presents a special difficulty, because oil adheres to it with great persistence. Petrolic ether will not remove it, nor will ethyl ether do so completely. After washing with the latter the pigment should be washed in a Soxhlet apparatus, with a mixture of one part acetone and three or four of benzole or chloroform; even then a trace of oil probably remains, for paste made from 98 per cent Pb_3O_4 gives on analysis only 96 to 97 per cent, and allowance should be made for this.

METHOD FOR ANALYSIS OF RED-LEAD[1]

OF

AMERICAN SOCIETY FOR TESTING MATERIALS

Approximate formula may be considered as Pb_3O_4 (probably $PbO_2 2PbO$).

Apparent gravity and true specific gravity determined as per methods under white pigments.

FINENESS.—Wash 10 g. with water through No. 21 silk bolting cloth; dry and weigh residue.

MOISTURE.—Dry 2 g. of the sample for 2 hours at 105° C. The loss in weight is considered as moisture.

ORGANIC COLOR.—Boil 2 g. of the sample with 25 cc. of 95 per cent ethyl alcohol; let settle, decant off the supernatant liquid; boil residue with water, decant as before and boil residue with very dilute NH_4OH. If either the alcohol, water, or NH_4OH is colored, organic coloring matter is indicated.

TOTAL LEAD AND INSOLUBLE MATTER.—Treat 1 g. of the sample with 15 cc. of HNO_3 (1:1) and sufficient hydrogen dioxide to dissolve all PbO_2 on warming. If any insoluble matter is present, add 25 cc. of water, boil, filter and wash with hot water. Insoluble contains free SiO_2, and should be examined for $BaSO_4$ and silicates, if appreciable. To original solution or filtrate from insoluble add 20 cc. of con-

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[1] This includes orange mineral.

centrated H_2SO_4 and evaporate to SO_3 fumes; cool, add 150 cc. of water and 150 cc. of 95 per cent ethyl alcohol, let stand cold two hours, filter on a Gooch crucible, wash with 95 per cent alcohol, dry at 105° to 110° C. and weigh as $PbSO_4$. Calculate to PbO. Red-lead is rarely adulterated, but should sample contain soluble barium compounds, the $PbSO_4$ obtained above will contain $BaSO_4$. In this case, digest above precipitate with acid ammonium-acetate solution, filter off $BaSO_4$, wash, ignite and weigh $BaSO_4$. Calculate to BaO or $BaCO_3$. In filtrate, determine the lead as $PbSO_4$ or $PbCrO_4$. If sample contains significant amounts of calcium or magnesium, the HNO_3-H_2O_2 solution is boiled till all lead is converted into nitrate and then lead determined as $PbCrO_4$. If Ca and Mg are to be determined, separate lead as PbS and proceed as under basic sulfate of lead in presence of these metals.

DETERMINATION OF LEAD PEROXIDE (PbO_2) AND TRUE RED-LEAD (Pb_3O_4). — (Method of Diehl,[2] modified by Topf[3]—not applicable when substances are present, other than oxides of lead, that liberate iodine under conditions given.)

Weigh 1 g. of finely ground sample into a 200 cc. Erlenmeyer flask, add a few drops of distilled water and rub the mixture to a smooth paste with a glass rod flattened on end. Mix in a small beaker 30 g. of c. p. "Tested Purity" crystallized sodium acetate, 2.4 g. of c. p. potassium iodide, 10 cc. of

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[2] Dingl. polyt. Jour., Vol. 246, p. 196.

[3] Zeitschrift für analytische Chemie, Vol. 26, p. 296,

water and 10 cc. of 50 per cent acetic acid; stir until all is liquid, warming gently; if necessary, add 2 to 3 cc. of H_2O, cool to room temperature and pour into the flask containing the red-lead. Rub with the glass rod until nearly all the red-lead has been dissolved; add 30 cc. of water containing 5 or 6 g. of sodium acetate, and titrate at once with decinormal sodium thiosulfate, adding the latter rather slowly and keeping the liquid constantly in motion by whirling the flask. When the solution has become light yellow, rub any undissolved particles up with the rod until free iodine no longer forms; wash off rod, add the sodium-thiosulfate solution until pale yellow, add starch solution and nitrate until colorless, add decinormal iodine solution until blue color is just restored, and subtract the amount used from the volume of thiosulfate that had been added.

CALCULATION.—The iodine value of the sodium-thiosulphate solution multiplied by $0.94193 = PbO_2$; the iodine value, multiplied by $2.69973 = Pb_3O_4$; the PbO_2 value, multiplied by $2.86616 = Pb_3O_4$.

THE SODIUM-THIOSULFATE SOLUTION (decinormal).—Dissolve 24.83 g. of c. p. sodium thiosulfate, freshly pulverized and dried between filter paper, and dilute with water to 1 liter at the temperature at which the titrations are to be made. Solution best made with well-boiled H_2O free from CO_2, or let stand 8 to 14 days before standardizing. Standardize with pure, resublimed iodine, as described in Treadwell-Hall, "Analytical Chemistry," Vol. II,

p. 602 (1910), and also against pure potassium iodate. The two methods of standardization should agree within 0.1 per cent on iodine value.

STARCH SOLUTION.—Two or three grams of potato starch are stirred up with 100 cc. of 1 per cent salicylic-acid solution, and the mixture is boiled till starch is practically dissolved, then diluted to 1 liter,[4] or as per Lord.[5]

ZINC.—If in appreciable amount, determine in filtrate from total lead as per methods under zinc white, evaporating off the alcohol.

WATER-SOLUBLE.—Digest 10 g. of sample with 200 cc. of hot water on steam bath for one hour; filter on an 11-cm. S. & S. blue-ribbon paper and wash with hot water till no residue is left on evaporating a few drops of the washings. Evaporate filtrate to dryness on steam bath in a weighed dish, dry 30 minutes at 105° C., cool and weigh. Take up with water and if alkaline, titrate with 0.1 normal acid and methyl orange; calculate to Na_2CO_3. Another lot of water-soluble matter is tested for nitrates, nitrites, carbonates, sulfates, sodium and lead.

TOTAL SILICA.—Digest 5 g. of the sample in a covered casserole with 5 cc. of HCl and 15 cc. of HNO_3 (1:1). Evaporate to dryness to dehydrate. Cool, treat with hot water and HNO_3, boil, filter,

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[4] Lead Peroxide.—If sample contains an appreciable amount of nitrite (nitrate has no effect on method), leach out water-soluble matter as below, dry residue, and determine PbO as above, calculating to basis of original sample.

[5] Notes on Metallurgical Analysis, p. 103 (1903).

wash with hot acid ammonium-acetate solution, then dilute HCl and finally hot water. Ignite and weigh as SiO_2. The residue may be treated with H_2SO_4 and HF in cases of doubt as to purity.

CARBON DIOXIDE.—Determined by evolution method, using dilute HCl and stannous chloride.

SOLUBLE SULFATE.—Determined as under basic sulfate of lead.

IRON OXIDE.—Determined by Schaeffer's[6] modification of Thomson's colorimetric method; or, in a large beaker, treat 20 g. of the sample with 20 cc. of water, 20 cc. of HNO_3 (sp. gr. 1.4) and 3 cc. of formaldehyde solution. Warm till all PbO_2 is dissolved, dilute with water, warm, filter off insoluble and wash with hot water. Ignite filter and insoluble, evaporate with H_2SO_4 and hydrofluoric acid. To filtrate from insoluble add 14 cc. of H_2SO_4 (1 :1), filter off $PbSO_4$, wash. Residue from HF and H_2SO_4 is dissolved in H_2SO_4 and added to filtrate from $PbSO_4$; dilute to 500 cc. and determine Fe colorimetrically in an aliquot, using same amounts of HNO_3, H_2SO_4 and formaldehyde in comparison solution.[7] Calculate to Fe_2O_3.

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[6] Journal of Industrial and Engineering Chemistry, Vol. 4, p. 659, (1912).

[7] Chemisch-technische Untersuchungs-Methoden, Lunge, Berl., Bd. 2, S. 95, 6th Ed.


CONNECTING TERMINAL ELEVATOR BUFFALO
RANDOLPH WORKS RANDOLPH WIS.
D. L.&W.R.R. TERMINAL BUFFALO

Determination of Pb_3O_4

(National Lead Company Laboratory)

1. "RED-LEAD SOLUTION."—Weigh out into a 1300 c. cm. beaker, 600 grammes c. p. crystalline sodium acetate and 48 grammes c. p. potassium iodide. Make up a solution of 25 per cent acetic acid, by mixing 150 c. cm. c. p. glacial acetic acid with 450 c. cm. distilled water. Now pour about 500 c. m. of this 25 per cent acid into the 1300 c. cm. beaker, above mentioned, reserving the remainder. Warm the beaker on the steam-bath, stirring occasionally, until a clear solution is obtained. Cool this solution to room temperature, and pour it into a 1-litre graduated flask. Then add enough of the reserved 25 per cent acetic acid to make exactly 1000 c. cm. and mix thoroughly.

2. ONE-TENTH N SODIUM THIOSULPHATE SOLUTION.—Weigh out into a large beaker 25 grammes c. p. crystalline sodium thiosulphate; add 400-500 c. cm. distilled water, and stir until dissolved. Wash this solution into a 1-litre graduated flask, make up to the mark with distilled water, and mix thoroughly.

Each c. cm. of this solution is equivalent to about 3.48 per cent true red-lead (using 1-gramme charge), but its exact value should be determined by standardizing against pure iodine or, better, against a standard sample of red-lead, the "true red-lead" content of which is accurately known. The strength of this solution gradually decreases upon standing. It is a good plan, therefore, when analyzing a sample of red-lead, to run a parallel determination with the standard red-lead, thus ascertaining the exact strength of the thiosulphate solution. This procedure consumes but little extra time and will often prevent error.

3. STARCH-INDICATOR SOLUTION.—Weigh out ½ gramme of ordinary starch into a small beaker, add 10 c. cm. cold distilled water, and mix to a thin paste. Measure into another beaker 100 c. cm. distilled water, heating to boiling, and pour into it slowly, with constant stirring, the previously prepared starch paste. Then boil for two minutes, with constant stirring. This solution does not keep well and should be prepared fresh for each day's work.

METHOD.—Weigh 1 gramme of sample into a 300 c. cm. Erlenmeyer flask. Add a few drops of distilled water and rub the mixture to a smooth paste with a glass rod. Then add 50 c. cm. of the "red-lead solution" and continue rubbing with the glass rod until nearly all the red-lead has been dissolved. Remove the rod from the solution and wash it off with 25 c. cm. of distilled water, making sure that all washings run into the flask. Titrate at once with the one-tenth , N thiosulphate, adding the latter rather slowly and keeping the liquid constantly in motion by whirling the flask. When the color of the assay has been reduced to a light yellow, examine it carefully for undissolved particles of red-lead. If present, they can often be dissolved by shaking the flask for a short time, but if they dissolve too slowly, they should be crushed by rubbing again with the glass rod, until completely dissolved. The rod should then be removed and washed with a few cubic centimeters of water. After the addition of thiosulphate has reduced the color of the assay to a very pale lemon tint and care has been taken to see that solution of the red-lead is complete, add 2 c. cm. of the starch-indicator solution. The assay should then turn blue. Now finish the titrating by adding the thiosulphate solution, drop by drop, shaking the flask very thoroughly after each addition, until the blue color disappears.

CALCULATION.—Suppose, for instance, that a red-lead sample, by this method, requires 24.8 c. cm. of thiosulphate solution, and that the laboratory standard red-lead requires 26.5 c. cm. of thiosulphate.

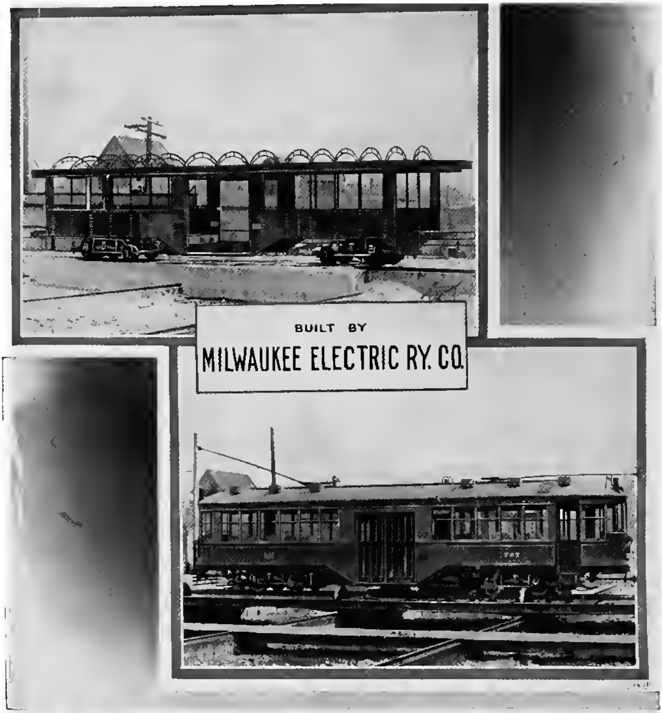
Then the per cent "true red-lead" in the sample is:

$$\frac{92.00}{26.5}\times 24.8 = 86.7 \text{ per cent ``true red-lead.''}$$

NOTES.—Before analyzing a coarse sample, "glassmakers' red-lead," for instance, it is necessary to grind the sample, thus rendering it more readily soluble.

Never attempt to hasten solution of the sample by warming, as this will cause loss of iodine, and, consequently, too low a result. The "red-lead solution" should be kept in a cool, dark place, but even then, however, it may gradually decompose, with liberation of iodine. The error thereby introduced, in a determination, is not appreciable if the thiosulphate is freshly standardized, before use, against a standard sample of red-lead, as recommended.

The main consideration, in this method, is to see that the determination is run in exactly the same way, and under exactly the same conditions, as the standardization of the thiosulphate, by means of the standard sample of red-lead. Then any small errors in the determination will be offset by similar errors in the standardization.



BUILT BY
MILWAUKEE ELECTRIC RY. CO.

BUILT BY
PRESSED STEEL CAR COMPANY
PITTSBURGH PA.

FORMULAS

Red, for First Coat

100 lbs. Dutch Boy Paste Red Lead
2.5 gals. linseed oil (measured)
1 pint turpentine
1 pint drier

4.85 gallons of paint

Light Brown, for Second Coat

100 lbs. Dutch Boy Paste Red Lead
½ lbs. paste lampblack
2.65 gals. linseed oil (measured)
1 pint turpentine
1 pint drier

5.1 gallons of paint

Gray, for Light Finish

One coat covers over Red

100 lbs. Paste White Lead
4 oz. paste lampblack
8 oz. paste French ochre
4 gals. linseed oil (measured)
1 pint turpentine
1 pint drier

7 gallons of paint

Dark Brown, for Third Coat

100 lbs. Dutch Boy Paste Red Lead
6 lbs. paste lampblack
3.64 gals. linseed oil (measured)
1 pint turpentine
1 pint drier

6.67 gallons of paint

Dark Green

100 lbs. Dutch Boy Paste Red Lead
12½ lbs. paste chrome yellow medium
7½ lbs. paste Prussian blue
4.54 gals. linseed oil (measured)
1 pint turpentine
1 pint drier

8.1 gallons of paint

Black

100 lbs. Dutch Boy Paste Red Lead
52 lbs. paste lampblack
16 lbs. paste Prussian blue
15.2 gals. linseed oil (measured)
1 gal. turpentine
1 gal. drier

26.5 gallons of paint

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APPENDIX II

SPECIFICATIONS FOR PAINTING BRIDGES

Three Coats on New Bridges

1. Before leaving the shops all structural metal shall be cleaned of all mill scale that can be scraped off and of all dirt, rust and oil, and receive one coat of pure red-lead and linseed oil paint as specified in paragraph No. 4. This shall be dry to the touch before the metal is shipped. All surfaces which will be inaccessible after erection (field riveted and bolted joints) shall have a specially heavy coat.

2. After erection all structural metal shall be cleaned to the satisfaction of the inspector. All abraded or unpainted surfaces shall be painted. When this paint is dry the entire surface shall receive one coat of pure red-lead and oil paint, mixed as specified in paragraph No. 4, to which has been added two ounces of paste lampblack to each gallon of paint.

2a. After erection and before the first field coat as specified above, all rivet-heads and bolt-heads shall be painted an extra coat, and so also shall be all edges and angles to a distance of an inch from the edge. After drying, the first full field coat, as specified in paragraph No. 2, shall be applied over the whole.

3. At least a week shall elapse before another coat of paint is applied. If a dark color is desired, the bridge shall receive a coat of paint as specified in paragraph No. 4, with the addition of one pound of paste lampblack to each gallon of paint; but if a light color is desired, the third coat shall be made by mixing 100 pounds of pure basic carbonate white-lead-in-oil (paste) with four ounces of paste lampblack, eight ounces of paste French ochre, four gallons of pure raw linseed oil, one pint of pure turpentine, and one pint of drier, free from rosin; this latter formula makes about seven gallons of paint.

4. The red-lead to be used shall contain not less than 94 per cent of pure red-lead (Pb_3O_4) and not more than one-half of one per cent of materials other than oxide or carbonate of lead; and not less than 99 per cent shall wash through a sieve of 200 meshes to the linear inch. If the red-lead is purchased dry it shall be mixed in the proportion of 28 pounds of pigment to one gallon of pure raw linseed oil; and if paste red-lead is used, 40 pounds of such paste, containing only pure red-lead and 6 to 7 per cent of linseed oil, with one gallon of pure linseed oil, and to a gallon of paint may be added at the discretion of the master painter or of the inspector one-third of a pint of turpentine and one-third of a pint of drier free from rosin.

Two Coats on New Bridges

1. Before leaving the shops all structural metal shall be cleaned of all mill scale that can be scraped off and of all dirt, rust and oil, and receive one coat of pure red-lead and linseed oil paint as specified in paragraph No. 3. This shall be dry to the touch before the metal is shipped. All surfaces which will be inaccessible after erection (field riveted and bolted joints) shall have a specially heavy coat.

2. After erection all structural metal shall be cleaned to the satisfaction of the inspector. All abraded or unpainted surfaces shall be painted. When this paint is dry, if a dark color is desired, the bridge shall receive a coat of paint as specified in paragraph No. 3, with the addition of one pound of paste lampblack to each gallon of paint; but if a light color is desired, the second coat shall be made by mixing 100 pounds of pure basic carbonate white-lead-in-oil (paste) with four ounces of paste lampblack, eight ounces of paste French ochre, four gallons of pure raw linseed oil, one pint of pure turpentine, and one point of drier, free from rosin; this latter formula makes about seven gallons of paint.

2a. After erection and before the first field coat as specified above, all rivet-heads and bolt-heads shall be painted an extra coat, and so also shall be all edges and angles to a distance of an inch from the edge. After drying, the field coat, as specified in paragraph No. 2, shall be applied over the whole.

3. The red-lead to be used shall contain not less than 94 per cent of pure red-lead (Pb_3O_4) and not more than one-half of 1 per cent of materials other than oxide or carbonate of lead; not less than 99 per cent shall wash through a sieve of 200 meshes to the linear inch. If the red-lead is purchased dry, it shall be mixed in the proportions of 28 pounds of pigment to one gallon of pure raw linseed oil; and if paste red-lead is used, 40 pounds of such paste, containing only pure red-lead and 6 to 7 per cent of linseed oil, with one gallon of pure linseed oil, and to a gallon of paint may be added at the discretion of the master painter or of the inspector one-third of a pint of turpentine and one-third of a pint of drier free from rosin.

Repainting Bridges

All rust shall be thoroughly removed by the use of substantial steel scrapers, aided by hammering if necessary, and then wire-brushed. All dirt and loose paint shall be cleaned off. Especial care shall be taken in cleaning the part under the deck or roadway. After this, all exposed metal surfaces shall have a coat of red-lead paint made by mixing either 28 pounds of dry red-lead or 40 pounds of paste red-lead with one gallon of pure linseed oil; to each gallon of such paint one-third of a pint each of turpentine and drier may be added. When this is dry, the bridge is ready for repainting and may receive such paint as may be specified; such as are described in the Specifications for Painting Bridges. Gates, if present, should be painted a distinctive and conspicuous color.

Exterior Ship Painting

The surface must be thoroughly clean and free from rust and loose scale; it then shall receive a coat of the following paint:

Paste red-lead	100 lbs.
Raw linseed oil	2⅛ gals.
Japan drier	1⅛ qts.
Turpentine	1⅛ "
	4.8 gals.

If it is desired to use three coats, the second should be the same as above with the addition of ¾ pound paste lampblack to the above formula; then the third coat (or if only two coats are desired, the second or finishing coat) shall be as follows:

Paste white-lead (carbonate)	100 lbs.
Paste French ochre	8 oz.
Paste lampblack	4 "
Pure linseed oil	4 gals.
Turpentine	1 pt.
Drier (free from rosin)	1 "
	7 gals.

If a darker gray is desired, more lampblack and ochre may be added.


"MISS MINNEAPOLIS"


"MISS DETROIT"

Interior Ship Painting

After thoroughly cleaning the metal surface, it shall be painted with a paint made as follows:

Paste red-lead	100	lbs.
Pure linseed oil	2	gals.
Turpentine	½	"
Drier	1¼	pts.
	4¾	gals.

When this is thoroughly dry a second coat shall be applied of the following paint:

Paste white lead (carbonate)	100	lbs.
Paste French ochre	8	oz.
Paste lampblack	4	"
Pure linseed oil	3	gals.
Turpentine	1	qt.
Drier	1½	pts.
	6	gals.

This is to be a rather heavy full coat.

If a pure white is desired, a third coat may be applied as follows:

Paste white-lead (carbonate)	100	lbs.
Pure linseed oil	3	gals.
Turpentine	1	qt.
Drier	1½	pts.
	6	gals.

Or a suitable varnish enamel paint may be used for the third coat.

NOTE.—The second coat, as above, is a light, warm gray, and one coat covers over red-lead, whereas no pure white paint will do this; for most places it is light enough in color, and it makes a good foundation for any paint.

Specification for Painting Water-Tanks

The surface shall be cleaned as thoroughly as possible, first, of all dirt, oil and grease; second, of scale, either (a) by the sand-blast or (b) by very thorough scraping and wire-brushing. It shall then be painted with the following paint:

For the interior, mix 100 pounds paste red-lead with two gallons of oil, or 100 pounds dry red-lead (containing not less than 95 per cent of Pb_3O_4) with three gallons of oil; the oil shall be pure boiled linseed oil of quality acceptable to the engineer; to this amount of red-lead and oil mixture shall be added 8 pounds of fine litharge, mixed in 1 pint of pure raw linseed oil and 1 quart of pure spirit of turpentine; this mixture of red-lead, litharge, oil and turpentine is the paint which is to be applied to the interior only. At suitable intervals two more coats of this paint shall be applied to the interior, each coat being allowed to become dry and hard before another coat is applied. If the tank is so formed or situated that it is not well ventilated, this shall be effected artificially by blowing air into it in sufficient quantity.

For the exterior, the paint shall consist, for the first coat, of 100 pounds paste red-lead and two and a half gallons of raw linseed oil, or 100 pounds dry red-lead (of not less than 94 per cent of Pb_3O_4) and three and a half gallons of oil; to this amount of red-lead and oil may be added one and a half pints each of drier and turpentine, if desired.

For the second coat, to a similar red-lead paint three-quarters of a pound of paste lampblack may be added; and for the third coat, 100 pounds of paste white-lead (carbonate), 8 ounces of paste French ochre, 4 ounces of paste lampblack, 4 gallons of raw linseed oil, 1 pint of drier and 1 pint of turpentine.

Painting Gas-Holders

The paint specified for water-tank interiors will be found suitable for the under coats of gas-holders, but if thought desirable it may be thinned somewhat with turpentine; 1 quart of additional turpentine being sufficient for the quantity of paint already mentioned. The finishing coat should be like the light gray finishing coat for water-tanks.

Architects' Painting Specifications for All Iron, Steel and Other Metal Work

1. STRUCTURAL IRON AND STEEL BEFORE ERECTION.—Before leaving the shops all structural iron and steel work shall be cleaned of all loose mill scale,

dirt, rust and oil and receive one coat of pure red-lead and linseed oil paint as specified in paragraph No. 5. All surfaces which shall be inaccessible after erection shall receive two coats of the same paint before erection.

2. STRUCTURAL IRON AND STEEL AFTER ERECTION.—All structural iron and steel shall be cleaned after erection. If there are any abrasions in the paint, they shall be repainted with the paint specified above, after removing all foreign substances with a stiff wire brush. After retouched places have dried, the entire surface shall receive one coat of pure red-lead-in-oil, mixed as specified in paragraph No. 5 with the addition of 2 ounces of lampblack in oil to each gallon of paint. Where the iron or steel is to be exposed add a third coat of red-lead-in-oil mixed as specified in paragraph No. 5, with the addition of 1 pound of lampblack in oil to each gallon of paint.

3. INTERIORLY EXPOSED METAL.—All interiorly exposed metal such as pipes, automatic sprinklers, steam and hot water radiators, elevator shafts and stairways, shall receive two coats of pure red-lead and oil mixed as specified in paragraph No. 5. Where the color of the red-lead does not conform to the color scheme, pure basic carbonate white-lead and oil paint tinted as desired shall be applied over the red-lead paint.

4. EXTERIORLY EXPOSED METAL.—All exteriorly exposed metal surfaces such as tin, galvanized iron, iron and steel, cast iron, iron or steel used in roof-

ing, cornices, valleys, gutters, down-spouts, railings, gratings, fire escapes, smoke stacks, etc., shall receive two coats of pure red-lead and oil paint, mixed as specified in paragraph No. 5. Where the color of the red-lead does not conform to the color scheme, pure basic carbonate white-lead and oil paint tinted as desired shall be applied over the red-lead paint. All metal roofings, including valleys, shall receive one heavy coat of pure red-lead and oil paint on the under surface, mixed as specified in paragraph No. 5.

5. FORMULA FOR MIXING RED-LEAD WITH OIL. —The red-lead to be used shall contain not less than 94 per cent of true red-lead (Pb_3O_4) and not more than one-half of 1 per cent of materials other than oxide or carbonate of lead; and not less than 99 per cent shall wash through a sieve of 200 meshes to the linear inch. If the red-lead is purchased dry it shall be mixed (preferably by grinding in a mill) with pure raw linseed oil, conforming to the specifications of the American Society for Testing Materials, in the proportion of 28 pounds of pigment to one gallon of oil; to each gallon of such paint may be added at the discretion of the master painter or of the inspector not more than one-third pint of pure turpentine japan drier; and if red-lead ground in oil is purchased, it shall contain nothing but pure red-lead and pure linseed oil agreeing with the above specification, and shall be mixed with linseed oil and drier in proportions of 40 pounds of Dutch Boy red-lead-in-oil to 1 gallon of pure raw linseed oil.

Notes

The U. S. Navy and U. S. Engineers' specification for red-lead is followed in these specifications, and calls for dry red-lead containing not less than 94 per cent Pb_3O_4, or paste made from red-lead of not less than 97 per cent Pb_3O_4 with a content of 6 to 7 per cent raw oil.

This red-lead specification is rather elaborate. If paste red-lead is used the following will be adequate:

The paste shall contain only red-lead and 6 to 7 per cent of linseed oil, and shall be guaranteed for three months against hardening if kept sealed in the original package at ordinary temperature.

But if dry red-lead is used it is at least necessary to specify the per cent of Pb_3O_4; if this is sufficiently high it is sure to be fine and pure; the U. S. Navy and U. S. Engineers insist on not less than 94 per cent.

The American Society for Testing Materials has a specification for North American raw linseed oil which calls for sp. g. at 15° C. from 0.936 to 0.932, acid No. not over 6, saponification No. 195 to 189, iodine No. (Hanus) not less than 180. (South American oil may have the iodine number as low as 170.) A good specification for linseed oil is that it shall agree with the specification of the American Society for Testing Materials, shall be aged at least one month, and a sample after standing twenty-four hours in a graduated cylinder at a temperature of not less than 70° F. shall not show more than one and a half per cent of sediment, by volume. A specification calling for pure, well-settled linseed oil would probably be sufficient in law.

The A. S. T. M. specification for boiled linseed oil names sp. g. at 15.5° C. to be 0.945 to 0.937, acid No. not over 8, sapon. No. 195-189, iodine No. (Hanus) not under 178, manganese, not under 0.03, lead, not under 0.1, calcium, not over 0.3.

It is to be noted that in these specifications for new work it is said that all loose scale shall be removed. A much more thorough cleaning is sometimes insisted on by the use of the sand-blast. Several railroads and some muncipalities use the sand-blast for cleaning old bridges, either in whole or in part, but such work is not here included.

In the "new bridge" specification the paragraph 2a may be struck out, if thought best; but it is practised by some of the best engineers. Rivet-heads and angles always rust first, and it is prudent and economical to give them an extra coat when new. This is especially important in case of two-coat work; two coats are not enough.

The white-lead, ochre and lampblack paint recommended is a light stone color, and one heavy coat will cover over red-lead; it is standard in one or two states and is practically what is used on the New York City bridges for an outside coat over red-lead. No adulteration of the white-lead should be allowed or the red-lead will show through.

Paste paints should be thinned as follows:

At first a little oil is added to the paste, and worked into it with a paddle; then add a little more oil, and so on until it is of the required consistency. Where paste colors are used for tinting, these are separately thinned with part of the oil in the same manner and finally mixed together. It is also good practise to pour the finished product through a fine sieve or cheese-cloth. All professional painters are familiar with these methods.

All cavities which may fill with water should be drained, or filled with cement; this is not a matter for the painter; but paint will not give much protection to surfaces which are exposed to ice, and to freezing and thawing.

Painting bridges which are not thoroughly cleaned is a waste of material and labor. In painting highway bridges particular attention should be given to the metal immediately under the planking; and if the ends of the planks impinge against metal members, such places are apt to rust. The use of salt on sidewalks or roadways for removing ice is also a source of danger. In all painting it is essential to use good brushes and no brush more than 4 inches wide is advisable; also, the use of a brush fixed to a handle several feet long should be prohibited; such a contrivance is sometimes called by the painters a "man-helper."

In any or all of the foregoing formulas, raw linseed oil may be changed to a mixture of one-third to one-half boiled oil and the remainder raw oil, in which case the drier should be left out, but may be replaced by an equal amount of turpentine.

The formulas in this book are based on the U. S. gallon, and if the book comes into use by readers who use the English or imperial gallon (which is one-fifth larger) the amount of red-lead should be increased one-fifth, and the surface covered is correspondingly more. Two tables will be found giving formulas and prices in English units; but these English formulas are not the equivalent of the apparently similar U. S. formulas, because while the pounds are the same pounds the gallons are larger gallons, hence a given number of pounds of pigment to a gallon of oil (or paint) makes thinner paint than that made on the United States formulas. Thus a paint made on the basis of 28 pounds of dry red-lead to the United States gallon of oil would be the same paint as if made of 33.6 pounds to one imperial gallon of oil, and of course this 33.6 pounds of red-lead plus 1 imperial gallon of oil makes 1.38 imperial gallons of paint the same as 28 pounds plus a gallon of oil makes 1.38 gallons of paint in United States measures. This is shown in the tables, in which some, but not all, of these relations are exhibited.

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